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DATA ACQUISITION SYSTEM FOR UNSTEADY AERODYNAMIC INVESTIGATION.

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THESIS

DATA ACQUISITION SYSTEM FOR UNSTEADY AERODYNAMIC INVESTIGATION

by

Cleveland Duane Englehardt

June 1977

Thesis Advisor: Louis V. Schmidt

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This paper describes the design and implementation of a microprocessor based high-speed digital data acquisition and reduction system suitable for use in time-varying signal analysis as encountered in unsteady aerodynamic investigation. A microprocessor, flexible disk drive and an analog-to-digital conversion module were the main components which were integrated to form a 32 channel, 12 bit resolution data acquisition system capable of 1000 Hz sampling rate and permanently

storing over 250,000 bytes of data on magnetic diskette. Subsequent to the data logging process, the same system was capable of serving as a general purpose computer utilizing the popular BASIC scientific programming language.

The system was qualified for accuracy and functional performance through a series of controlled exercises, and was then applied to an actual investigative task to further determine its utility and value.

DATA ACQUISITION SYSTEM FOR UNSTEADY AERODYNAMIC INVESTIGATION

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

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June 1977

ABSTRACT

This paper describes the design and implementation of a microprocessor-based high-speed digital data acquisition and reduction system suitable for use in time varying signal analysis as encountered in unsteady aerodynamic investigation. A microprocessor, flexible disk drive and an analog-to-digital conversion module were the main components which were integrated to form a 32 channel 12 bit resolution data acquisition system capable of 1000 Hz sampling rate and permanently storing over 250,000 bytes of data on magnetic diskette. Subsequent to the data logging process, the same system was capable of serving as a general purpose computer utilizing the popular BASIC scientific programming language.

The system was qualified for accuracy and functional performance through a series of controlled exercises, and was then applied to an actual investigative task to further determine its utility and value.

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I. INTRODUCTION

Data acquisition systems have historically been both costly and cumbersome for the investigator to use. Acquisition of unsteady experimental data, as in the case of oscillatory flow investigation, was only possible with the aid of expensive digital computer systems used in conjunction with elaborate analog recording devices.

Within the past four years, a new form of computing power has become available to the engineer accompanied by such a reduction in cost that its use has spread rapidly throughout the realm of engineering design. The revolutionary device alluded to is the microprocessor, which in its basic form contains all the arithmetic and logical functions normally found in the central processing unit (CPU) of a large scale computer. Concurrent advances in solid state memory and other large scale integrated (LSI) circuitry has enabled entire computing systems to be encased in table-top enclosures at a fraction of the cost of the previously available minicomputers.

This document describes the use of one such microprocessor-based microcomputer system, the INTEL MDS-800 Microcomputer Development System, as a central component of a data acquisition system . The MDS was integrally connected with various peripheral devices including an analog to digital converter, input-output devices, and a dual flexible disk drive unit to form a data acquisition system. The system was then qualified using known input signals of controlled harmonic content. Subsequently the system was applied to an actual experimental situation,

where unsteady analog signals were digitized, recorded, and later analyzed on the same self-contained computing system.

A glossary of terms commonly used in the instrumentation engineering, data processing and computing disciplines is presented in Appendix A.

II. System Design

An engineering design is, in general, the result of a directed effort in meeting a recognized human need or desire. The value of the design is usually determined by how well the design product satisfies a set of performance criteria. In most cases, several methods of achieving the goal will be available, thus requiring the designer to choose among the alternative approaches. This choice will be governed or influenced by constraints imposed by the environment, funding and production schedule.

This section deals with the definition of the need, specification of the desired performance attributes, determination of viable alternatives, and the decision process by which the final product was developed. Although most of the desired performance requirements were achieved, the project served as an educational experience revealing many areas which could be improved. Section VII discusses the design in retrospect and proposes additional alternatives which could further enhance the system's performance.

A. Definition of the "need"

The "need" was a precipitant of the Circulation Controlled Rotor (CCR) aerodynamic investigation being conducted by Naval Postgraduate School personnel. Existing wind-tunnel data acquisition systems were designed to operate in the steady-state flow-field environment. The

desire to study the dynamic nature of the flow about an airfoil of radical design, while experiencing the effects of an oscillatory flow-field, required a departure from the traditional hand logging or slow-speed automatic data acquisition methods. More important, however, the experimental process not only required investigation of the CCR at various angles of attack and air speeds, as in the case of steady-state wind tunnel experimentation, but additionally introduced frequency, cavity pressure modulation amplitude and phase relative to flow field oscillation as variables. Thus, the CCR experiment required experimental investigation throughout an operating envelope bounded by 5 independent variables rather than the usual 2 associated with steady-state flow problems. This obviously increased the magnitude of the data acquisition problem far beyond the point of practicability for the conventional data logging methods at hand. A high-speed automatic data logging technique was clearly in order. Additionally, in order for large amounts of data to be efficiently analyzed, it was imperative that all information be recorded in a form which could be directly utilized by a digital computer.

The above rationale then became the basis for the following statement of the "need":

* A high-speed digital data acquisition system exhibiting performance attributes necessary to allow numerical analysis of the flow pattern about the surface of a CCR airfoil section, operating in the Naval Postgraduate School 2-foot by 2-foot oscillatory flow wind tunnel

* Function as a controlling device capable of automatically sequencing the Scanivalve mechanical multiplexors without operator intervention

* Perform the algebraic calculations necessary in reducing the data to analytic form

B. Determination of Performance Specifications

Anticipating a significant investment in equipment, and realizing that the CCR research project would some day be complete, it was determined that the system design should take future applications into consideration. For this reason, flexibility was incorporated as a major design goal, which necessarily resulted in a modification of the specifications from those actually required for the CCR task.

1. Analog to Digital Conversion (A/D)

In a typical data-sampling system, signal voltages representing varying physical parameters; e.g., pressure, temperature, position, velocity and acceleration, are sampled and converted via A/D converters into digital form. A/D conversion has become an engineering discipline in itself and an entire vocabulary associated with the field has resulted. To assist the reader in understanding the following treatment of A/D performance requirements, a brief glossary of A/D terminology is included within Appendix A. In the interest of brevity, the discussion herein is limited to the most important facets of A/D conversion. For a more complete treatment of the subject, the reader is directed to ref. 12, an outstanding collection of A/D related articles.

As a prelude to the below listed performance parameters, Fig 1 depicts all of the elements found in a typical A/D conversion system and illustrates the type of errors associated with each stage of the process.

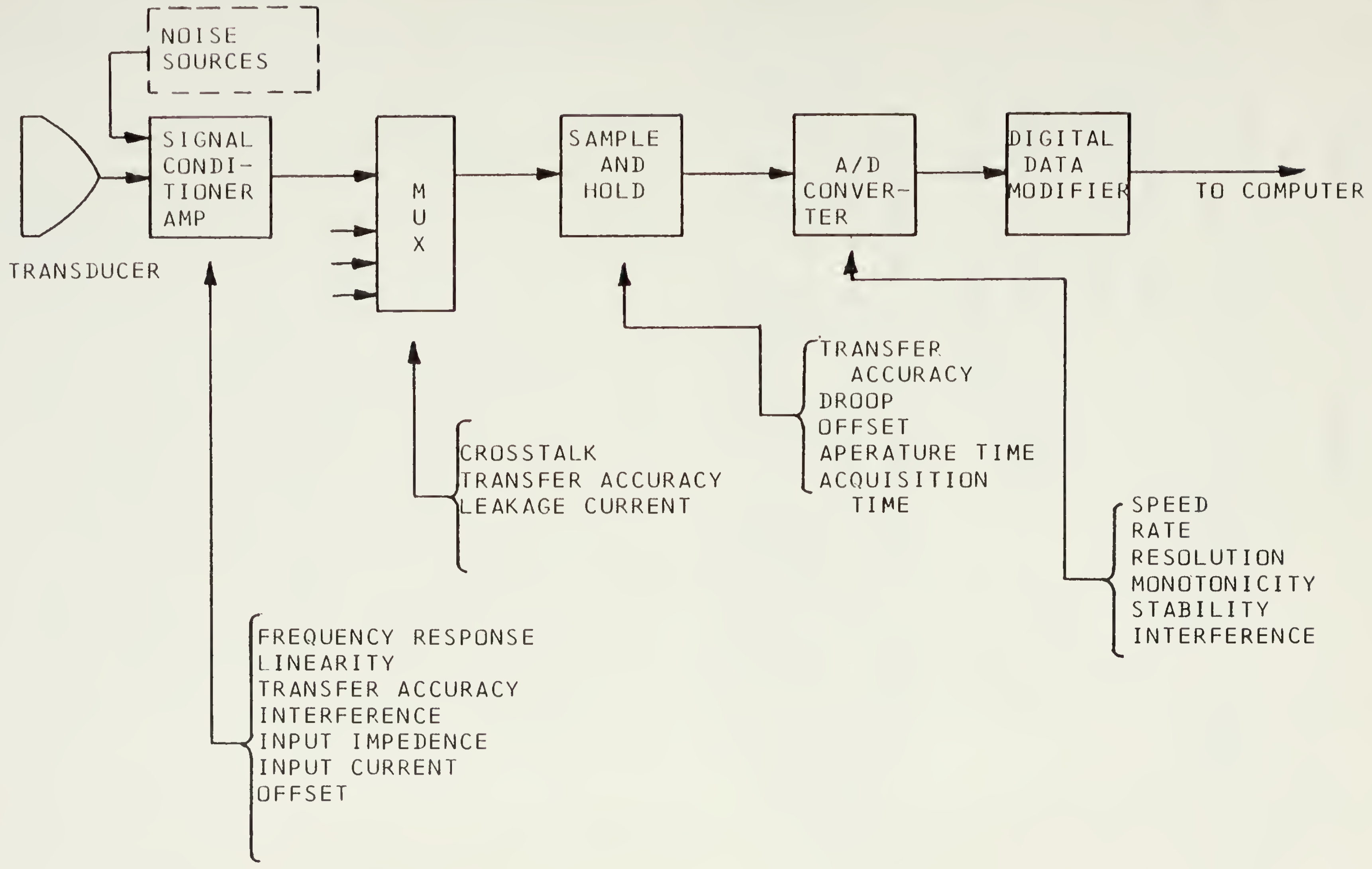


FIGURE 1 - TYPICAL ANALOG-TO-DIGITAL DATA ACQUISITION MODULE

2. Number of Analog Channels

The CCR experimental set up had one analog channel dedicated to each of the below listed signal sources:

* Scanivalve ONE

* Scanivalve TWO

* Cavity Pressure Transducer

* Hot Wire Annemometer

A schematic of the signal flow is depicted in Fig 2. The four channels were to be sampled in fast succession at a specified periodic rate. The A/D module had provisions for 32 single-ended channels or 16 differential channels. The single-ended mode was employed in this application.

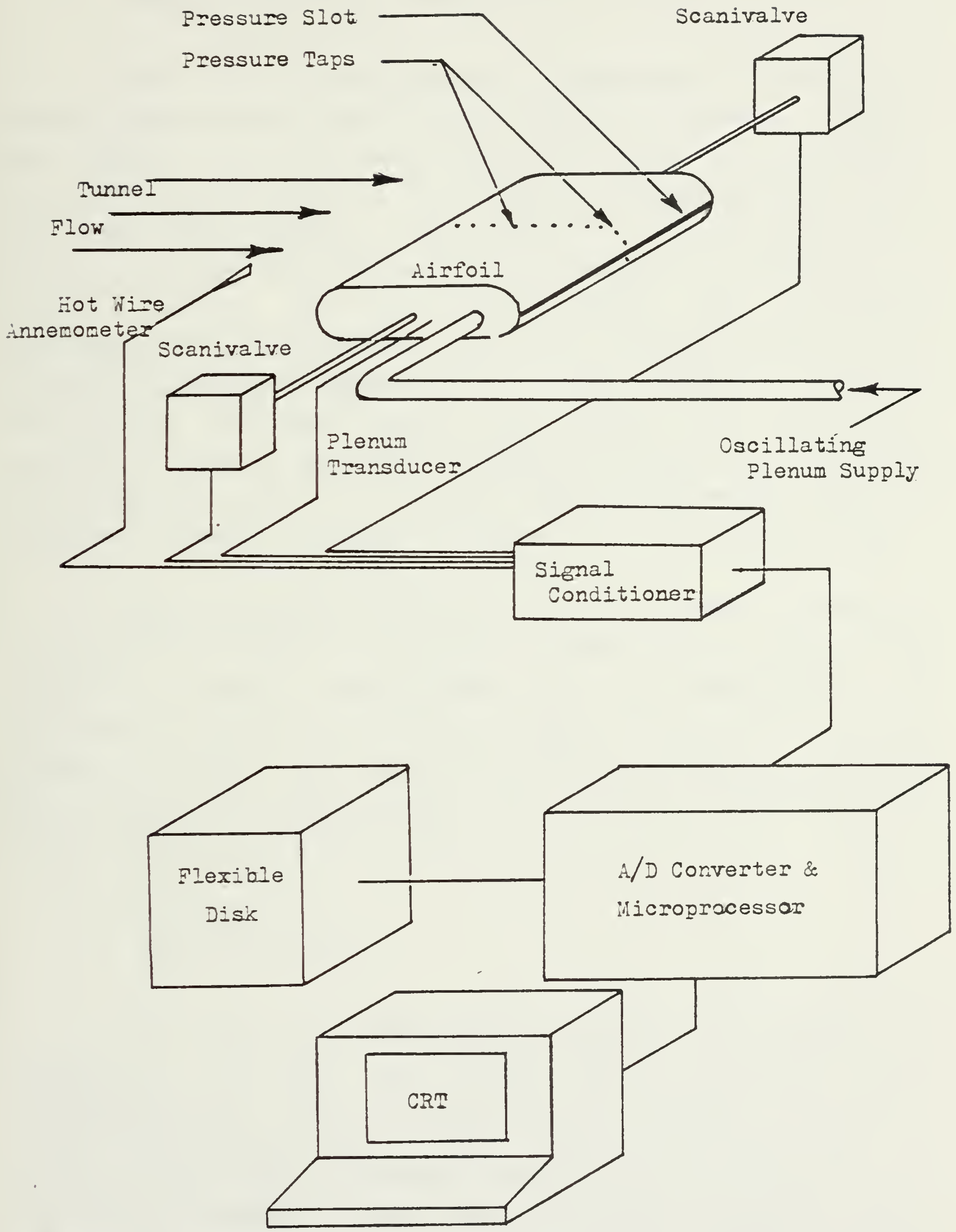


FIGURE 2 - CIRCULATION CONTROL ROTOR EXPERIMENTAL SIGNAL FLOW

3. Sample Resolution (quantization error)

When the analog signal is digitized, the resulting digital quantity can take on only certain discrete values. The number of bits in the digitized datum word determines the number of possible states that the word may have. An 8 bit A/D, for example, can exhibit 2 to the 8th or 256 states. If the range of operation of the A/D is minus 5 to plus 5 volts, (10 volts full scale), then each bit represents an increment of .0391 volts. This amounts to a resolution or quantization error of 0.391 percent. The more bits in the digitized word, the better the resolution; however, the price paid for increased accuracy is a decrease in conversion speed. Of course, speed and accuracy may be obtained concurrently with a corresponding increase in cost.

The A/D module exhibited 12 bit accuracy, yielding a quantization error of 0.024 percent over full range operation. This corresponded to a sensitivity of approximately 0.00244 volts during 10 volt full scale operation. The 12 bit converter offers moderate accuracy and relatively high speed, e.g. 75,000 conversions per second, for a reasonable cost.

4. Conversion Rate

The amount of time required for the A/D module to sample and digitize the analog input is defined as the conversion time. The A/D module was capable of 75,000 12-bit conversions per second, or one conversion every 13 microseconds. This conversion rate was only obtainable if the Direct Memory Access (DMA) mode were utilized. Since the SINETRAC-800 module was operated in the program control

mode, the conversion rate was limited by the microprocessor instruction sequence execution time to 74.5 microseconds per conversion. The resulting throughput was 13,400 conversions per second. The induced lag between channels caused significant problems in signal reconstruction and is discussed in detail in section IV.

C. The Processor

The digital processor was the heart of the system design, and added the flexibility needed to make the A/D conversion, data acquisition and storage process applicable to the problem at hand. The desired functional performance requirements of the processing unit are discussed in this section.

1. A/D control

During the acquisition phase of operation, the processor's main task was that of controlling the A/D module. By controlling the acquisition process under programmed logic, adjustments to the sampling rate, channel sampling sequence, and real-time filtering of the data could be easily effected.

The reconstruction of time-varying analog signals from a set of discrete datum points represents a problem of significant magnitude. Probably the single most important consideration during the acquisition phase is the period at which samples are to be taken. When investigating periodic signals, frequency content is generally a matter of prime interest. Nyquist's sampling theorem states that equi-spaced data, with two or more points per cycle of the

highest frequency, will allow reconstruction of band-limited functions. If this principle were not observed, a phenomenon termed "aliasing" could occur. The concept of aliasing is shown in Fig 3 which depicts a signal sampled at two different rates. The curves drawn through the two sets of points represent possible reconstructions of the original signal. The frequency change implied by the dotted curve is an "alias" of the frequency described by the solid curve.

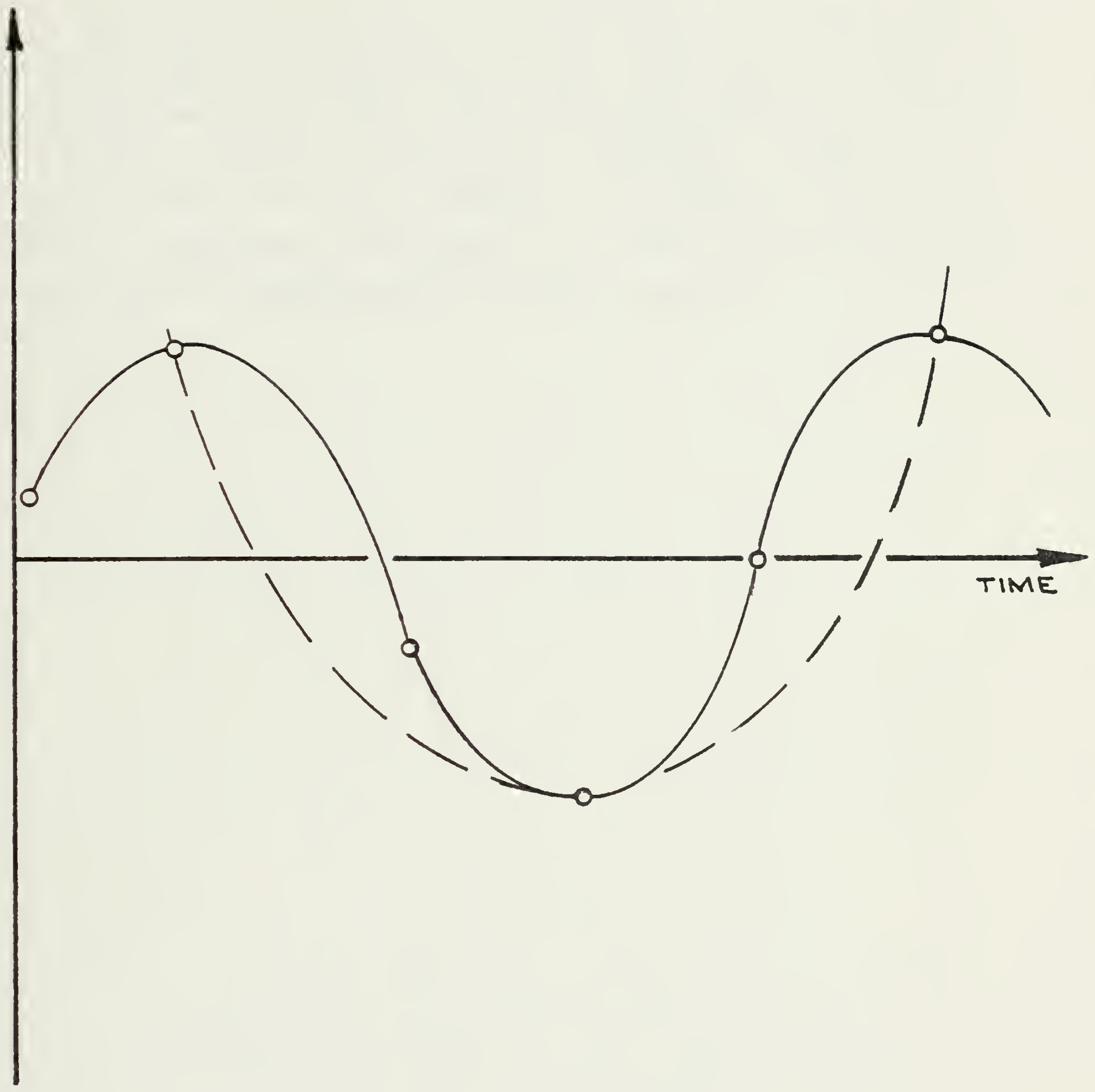


FIGURE 3 - "ALIASING" EFFECT

Other considerations related to sampling rate are the number of data points required for adequate analysis, the amount of memory, permanent mass storage, and computation time required in processing the data.

In the CCR application, it was predicted that fundamental driving frequencies in the range of 1 to 20 Hz should be investigated; and that frequency content up to the fifth harmonic would be of possible interest. This meant that the system must be capable of sampling the analog channels at a minimum rate of 200 Hz. The resulting design achieved a 500 Hz sampling rate over 8 channels.

III. HARDWARE

A. MDS-800 MICROCOMPUTER DEVELOPMENT SYSTEM

In its basic configuration, the INTEL MDS-800 Microcomputer Development System consists of a CPU, 16K RAM, peripheral interface controller, front panel controller, power supply and enclosure. With the exception of the enclosure and the power supply, each of the aforementioned items is in the form of one or more printed circuit modules which may be inserted into the mainframe of the MDS. The MDS may be directly connected to the following peripheral devices with minimal interfacing: CRT and keyboard console, high speed line printer, standard Teletype with paper tape reader and punch, high speed paper tape reader, and a high speed paper tape punch. This section describes the essential hardware elements of the system, an overall view of which is shown in Fig 4.

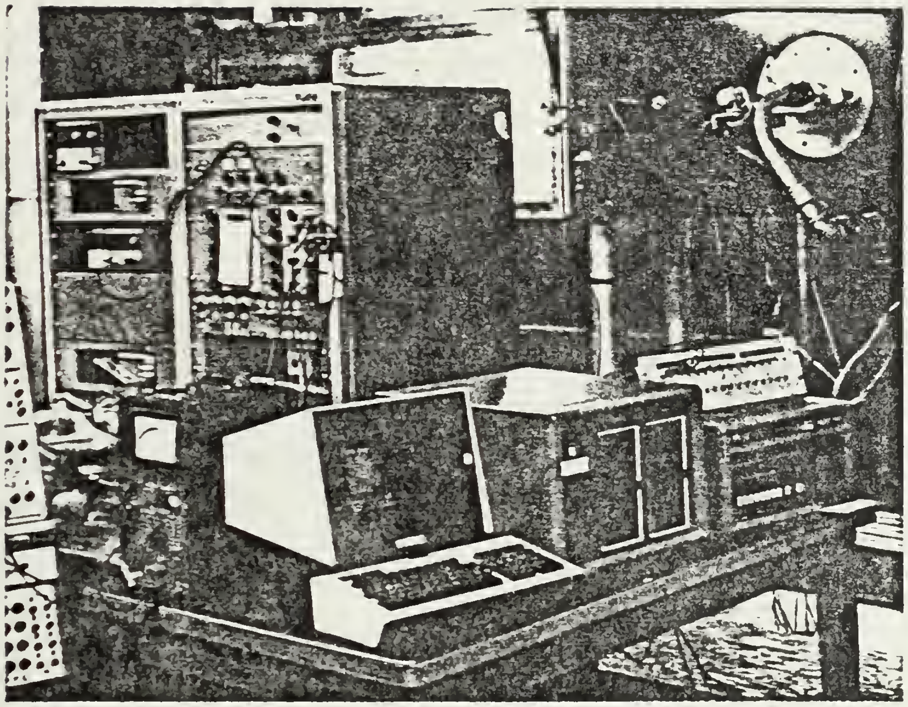


FIGURE 4 - MDS-800 MICROCOMPUTER DEVELOPMENT SYSTEM

1. Random access memory (RAM)

The basic block of RAM is a 16K byte module of high access rate volatile dynamic memory, where 1K denotes 2 to the 10th or 1024 bytes. The MDS is capable of addressing 4 such modules or 64K bytes of memory. Of the 64K of RAM only 62K are actually usable due to the coexistence of a 2K block of read only memory (ROM) containing the MDS Monitor program.

Due to the requirement for rapid recording of large blocks of data, the maximum number of RAM modules was installed. A RAM module is illustrated in Fig 5 and serves as an example of the typical insertable printed circuit modules referred to throughout this paper.

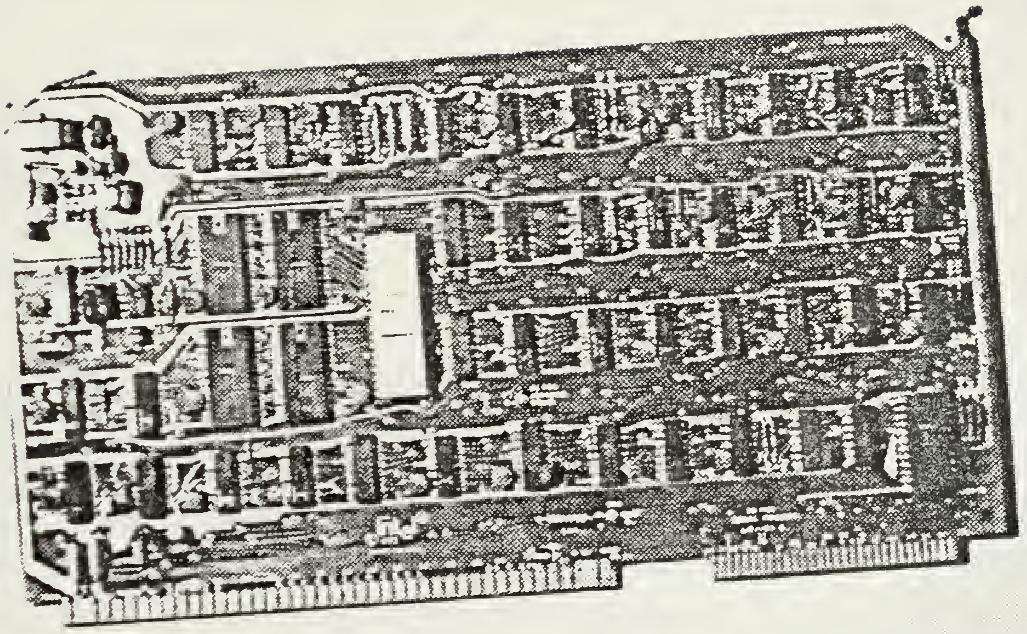


FIGURE 5 - 16K BYTE RANDOM ACCESS MEMORY MODULE

2. DISK OPERATING SYSTEM

The INTEL Disk Operating System (DOS) consisted of three major components, a dual floppy disk drive unit, a disk controller, and the DOS support software. The addition of the DOS provided dramatic increases in the flexibility, speed, and mass memory storage available.

Each 7.5-inch diameter floppy disk (diskette) had a capacity of 256K bytes of semi-random access storage. With the dual drive, over 0.5 million bytes of data, program, or other information could be accessed with relative ease and moderate speed.

The software support package offered by INTEL, called ISIS, was evaluated along with the Digital Research CP/M disk operating system. The Digital Research software package was chosen over the INTEL package due to the higher speed it demonstrated and its compatibility with the BASIC-E package used in the data reduction phase.

CP/M consists of several utility routines in addition to the Basic Disk Operating System (BDOS). These routines allow the user to form and edit disk files, programs or data files, to assemble and load assembly language programs, and a powerful debug routine. A more complete description of the CP/M BDOS is contained in ref. 9.

3. GENERAL PURPOSE INPUT OUTPUT MODULE (I/O)

The basic MDS-800 was further expanded with the installation of a general purpose I/O module. This module

provided four input ports and four output ports of eight bits each. The need for the I/O module was anticipated for control applications, digital input or outputs, controlling an X-Y plotter, or other general purpose applications. This module was actually intended for controlling the Scanivalve positioning under automatic channel sequencing. However, it was later decided that system flexibility would have been sacrificed had this feature been implemented.

4. SINETRAC-800 ANALOG TO DIGITAL CONVERTER MODULE

The Datel Sinetrac-800 A/D converter module is a 32 channel, 12 bit resolution analog to digital module specifically designed for use with the INTEL MDS-800. Being buss compatible with the MDS system, the module was installed within the MDS chassis and the wiring harness was brought to the backplane of the MDS enclosure.

The main elements of the A/D module were:

- 32 channel analog multiplexor
- sample and hold
- A/D converter sub-module
- addressing and hand-shaking logic circuitry
- Direct Memory Access control circuitry

The A/D module had three fundamental modes of operation:

- program control
- program control with automatic sequencing
- Direct Memory Access mode

Reference 1 contains a complete description of the A/D module including operating instructions and programming techniques.

Although the DMA mode was not utilized because of its requirement of an INTEL DMA module for support, future development of the system will make the addition of the DMA module indispensable. The use of DMA would allow the A/D module to operate at its full capability of 75 KHz sampling rate. This increase in acquisition rate would significantly extend the range of the system in terms of signal frequency component reconstruction.

The Sinetrac-800 also provided user options in certain operational parameter selection. Selectable by jumper wire were input signal voltage range (5, 10, or 20 volts), single ended or differential operation, and interrupt or non-interrupt operation. The options in use were: plus and minus 5 volt single ended, non-interrupt operation. Details concerning the use of jumper options are specified in ref. 1. The SINETRAC-800 is depicted in Fig 6.

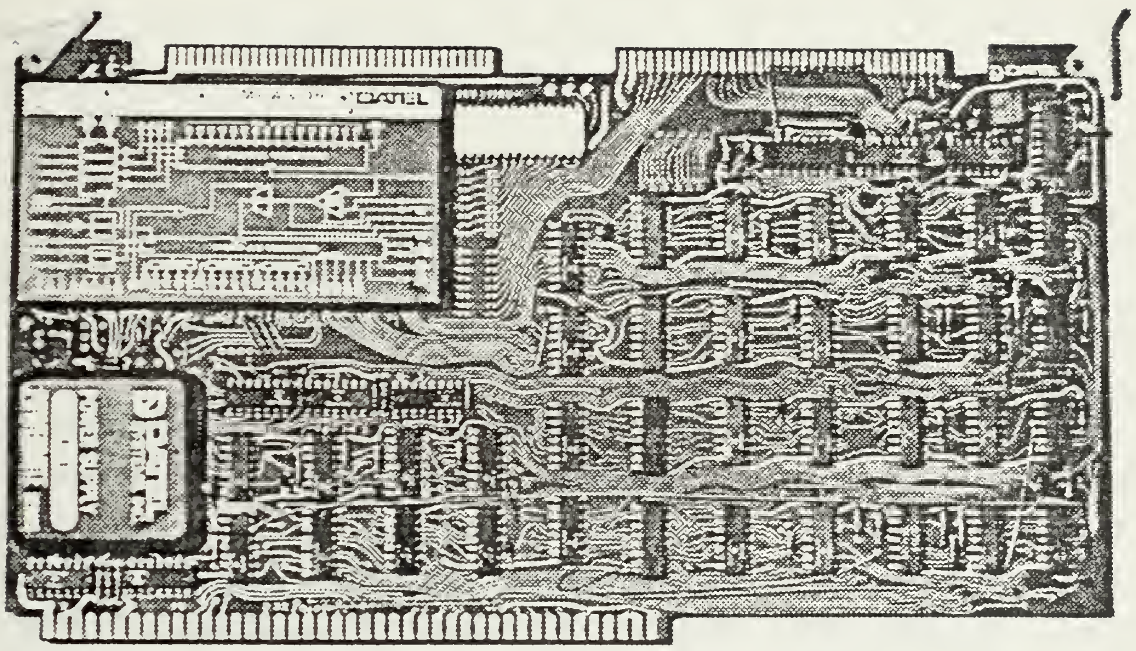


FIGURE 6 - SINETRAC-800 ANALOG TO DIGITAL CONVERTER MODULE

IV. SOFTWARE

The software development was accomplished in four distinct phases and involved the use of three different programming languages. This section briefly describes each language and the individual program modules created.

A. LANGUAGES

Every computer language has a level of application for which it was designed. The three languages discussed in this section were used to accomplish varying degrees of program control. A high level programming language allows the programmer to use nearly literal or sentence form expressions or equations. FORTRAN is an example of a high level language. A low level language on the other hand, is closely related to the machine code actually used by the computer. Machine code is, of course, the lowest level programming language but is rarely used. Low level languages provide the programmer with complete control over memory usage and CPU instruction sequences.

1. 8080 Assembly Language

This low-level language was specifically developed for use with the 8080 microprocessor. It is, however, similar in form to assembly languages in use with other computers. The form of the language is described fully in ref. 10, therefore only the merits of the language are

discussed herein.

The use of assembly language offers the programmer direct control over the CPU instruction sequence. Very efficient utilization of available program memory and optimization of program execution time may be accomplished when employed. These features form the basis for the use of assembly language in the construction of the data acquisition and ASCII conversion programs, where execution time and memory allocation are importrant considerations.

One distinct disadvantage to the use of assembly language is that the amount of work required in producing a relatively short program may be significant. Several pages of documentation are necessary to make the program readable, even to the author of the program. Obviously, tracing another's assembly language program is very difficult even with excellent documentation.

2. PL/M

PL/M is a medium-level language again designed for microprocessor use. It offers moderate control over the CPU instruction sequence while providing the user with many of the features available only in high-level languages. In other words, PL/M is a language which permits the user to determine, within limits, the degree of control he desires. The amount of machine code produced by PL/M compilation is about half again that resulting from a functionally equivalent assembly language program. PL/M is ideal for use when floating point mathematical operations are not required, or when time and memory efficiency are not important factors.

PL/M was used in the construction of the

communicatiions interface program called IFACE which linked the MDS-800 to the IBM-360 via telephone line. PL/M may be assembled on either the IBM-360 or locally on an MDS-800 when equipped with the full complement of 64K of RAM.

3. BASIC

BASIC is a high level language which is gaining wide acceptance throughout the scientific community. Similar to FORTRAN, BASIC provides the user with facility in programming mathematically complex routines in fairly familiar algebraic format. The BASIC-E compiler and run time monitor were developed for 8080 implementation to be used in conjunction with CP/M, and are fully described in ref. 5.

BASIC-E was used in the data analysis routine which may be easily modified to suit the user's needs. A summary of the commands available and syntax of BASIC-E can be found in ref. 6.

B. PROGRAMS AND DISKETTE FILES

The data acquisition and reduction process was a multiphase sequence, each phase consisting of one or more program executions. Each program resided on the system diskette under its individual file name. The system diskette also contained the CP/M BDOS and each of its associated utility routines, the BASIC-E compiler and run time monitor. The system diskette was inserted into disk drive A, while the data diskette was inserted into disk drive B. Each program module and its associated support files is described within this sub-section, and Appendix E

contains a description of the operating procedures.

1. CONTROL

A control file called CONTROL was formed prior to each acquisition run. This file was edited and maintained on the system diskette and contained both text and control parameters that were used by the acquisition program, ACQUIRE. The use of a control file eliminated the need for the operator to re-enter control parameters for successive runs. A sample CONTROL file is contained in Appendix F. The order of the passed parameters was significant; however, the verbiage or content of the string variables could be entered free-form. The ACQUIRE program would only recognize and use the integer value of parameters which were preceded by a colon and followed by a carriage return linefeed combination. The information following the first two colons was ignored, allowing the date and run number to be entered but not passed to the ACQUIRE program. The meanings of the parameters are self-evident from the sample shown in Appendix F, and are therefore not explained here.

2. ACQUIRE

ACQUIRE was the main program which performed the data acquisiton function. It would first read the CONTROL file from disk drive A and display it on the CRT for the operator's review. Should corrections or alterations be required, they could be effected at this time by editing the CONTROL file. With the CONTROL file in order, ACQUIRE proceeded to extract the necessary control parameters and duplicated the CONTROL file on the diskette in drive B. Using the extracted control parameters, this program then managed the operation of the SINETRAC-800 module, CRT, and

disk drive unit so as to scan the specified analog channels at the specified rate and number of repetitions, and record the data on the data diskette in disk drive B. The ACQUIRE program accomplished this task by issuing commands to the SINETRAC-800, followed by data to be written or read. The SINETRAC-800 was issued the initial and final channel numbers, a start scan command, and a start conversion command. When an analog to digital conversion was complete, the SINETRAC-800 changed its status word to indicate an end of conversion (EOC). The processor would then read in the two bytes of data resulting from the conversion. Upon receipt of a subsequent start of conversion command, the A/D module would automatically step to the next analog channel to be sampled and perform a conversion. When the entire range of channels was converted, the A/D would change the status word to indicate an end of scan, simultaneously resetting the channel selection register to the initial channel.

The generation of the scan period timing pulse is a topic which deserves explanation as it was one of the most difficult portions of the ACQUIRE routine from a programming standpoint. The MDS-800 front panel controller module includes an interrupt timer which may be turned on or off programmatically. The timer is actually a series of solid state counters which, after receiving a certain number of pulses from the 9.8 MHz system clock, issues a pulse to the CPU. This interrupts the operation of the 8080 CPU, causing the program to execute a subroutine. This subroutine then counts the number of interrupts received in this manner. When the number of interrupts counted reaches a value which matches that prescribed by the scan period control parameter entered by the CONTROL file, a scan instruction is issued to the SINETRAC-800 and a scan sequence is initiated. Each interrupt occurs at 0.977 ms. The fact that the timer interrupts at nominal 1 ms intervals became the limiting

factor on scan rate. In order to increase the scan rate, some other means of initiating the scan must be used. The rationale for using the interrupt timer in the first place was that it provided, at no additional expense, a highly accurate time base, an important requirement for dynamic signal analysis.

Data from each conversion were stored in sequential RAM locations. When the specified number of scans had been performed, the data stored in RAM were formatted and transferred to the data diskette in disk drive B. Each block of scans was written into a file called DATA.nnn, where nnn was the decimal sequence number for that file.

The process continued until all Scanivalve channels were sampled and logged, the diskette space was exhausted, or the process was terminated by the user. If the process were completed without mishap, a file called PROTECT could be written on the data diskette at the users option. The PROTECT file prevented further data from being recorded on an unprocessed diskette.

3. PROTECT

The PROTECT file, if it existed on a data diskette, prevented additional data from being written to the diskette. Normally the PROTECT file was only removed from a diskette upon successful completion of the reduction process. This procedure prevented unprocessed data from being inadvertently destroyed or overwritten. The PROTECT file could also be removed by typing "ERA B:PROTECT" at the console.

4. DATA.nnn

Each time the SCAN subroutine within the ACQUIRE program was executed, a DATA.nnn file was created on the data diskette. This file contained the data stream which resulted from one run. At the completion of all the runs the data diskette would contain several DATA files. For example, a completed data disk directory might be as follows:

```
CONTROL
DATA.000
DATA.001
DATA.002
PROTECT
```

The first 16 bytes of data on each DATA file form a header for that file, and contained the control information relevant to that file. The meaning of each byte within the header is listed below:

Byte 0	Initial Analog Channel
Byte 1	Final Analog Channel
Byte 2	Scanivalve One setting
Byte 3	Scanivalve Two Setting
Byte 4	No. of scans (LSB)
Byte 5	No. of scans (MSB)
Byte 6	Scan period (LSB)
Byte 7	Scan period (MSB)
Byte 8	Frequency (LSB)
Byte 9	Frequency (MSB)
Byte A through F	not used

Subsequent data words formed the body of the DATA file. A DATA file was composed of binary information, and

therefore required translation into ASCII characters prior to being read by the BASIC reduction routine.

5. CONVERT

The CONVERT program was an assembly language routine which read the desired DATA.nnn file into RAM, converted the binary values to ASCII decimal integers and created a file called DATA.ASC on the data diskette. This was necessary prior to each execution of the REDUCE program, as the BASIC-E file handling would only accommodate ASCII coded disk files. This process could have been made a part of the ACQUIRE program function; however, the additional number of bytes required for each data point would have severely limited the amount of data on each diskette.

The program was executed by typing "CONVERT DATA.nnn" at the console. The resulting ASCII type file could be viewed in raw unformatted form by typing "TYPE B:DATA.ASC".

6. REDUCE

The REDUCE program was written in BASIC and was executed by typing "RUN REDUCE" on the console. Its function was to read the DATA.ASC file from the data diskette and perform the required numerical analysis necessary to extract the Fourier coefficients of the signal wave form represented by the data. The program used is contained in Appendix C and a discussion of the reduction algorithm is presented in ref. 11.

It is important to note that the BASIC routine used in this application may be easily modified to suit the

user's needs. For that matter, an entirely different analysis algorithm could be substituted with equal facility. In effect, the function of the program was not of significance, however, it served as a vehicle for development and testing of the system. The demonstrated flexibility and ease in programming afforded by incorporation of the BASIC language are the meaningful features.

7. IFACE

This PL/M program was originally written by an unknown author but was adapted for use with the MDS-800 through modification of the interfacing routines.

Its purpose was to allow the user to operate the CRT console as a remote time-share terminal in conjunction with the W.R. Church IBM-360 operating under the Cambridge Monitoring System (CMS). The program listing is included for documentary purposes in Appendix C. It also provided for automatic bi-directional transfer of disk files between the IBM and MDS systems, a useful feature.

V. SYSTEM QUALIFICATION

Any design, whether hardware, software or a combination of both, must be thoroughly evaluated for performance under controlled conditions prior to its introduction in an actual field environment. The test which the design should undergo must exercise the device throughout its expected range of operation so that actual performance limitations may be determined. Qualification testing also provides the designer with quantitative and qualitative measures of the system's conformance to the design criteria. This section discusses the qualification tests conducted on the data acquisition system, and an interpretation of the results obtained.

The main objective of the qualification testing procedure conducted was to provide a level of confidence in the system's ability to faithfully track the input signals, thereby permitting the reduction routine to accurately perform numerical operations which would reconstruct the desired parameters of magnitude and phase, while filtering undesirable frequency components. The three basic qualification tests conducted in the determination of the system's performance characteristics are discussed below.

A. DC CALIBRATION

Accompanying the SINETRAC-800 D/A module was a voltage calibration and scan test software package. This program allowed verification of the accuracy of the A/D conversion

system when known (accurately measured) DC voltage levels were applied to the individual input channels of the A/D module. The results of this test, with the voltage range of the device set at plus and minus five volts full scale, are shown in Fig 7. This voltage range was chosen over the 20 or 5 volt full scale range because the outputs of the signal conditioning amplifiers had historically exhibited bias and excursion characteristics which remained well within this range. Had a 20-volt full-scale range been utilized, sensitivity would have been sacrificed, whereas a 5-volt range would have resulted in an overvoltage condition on the A/D converter circuit.

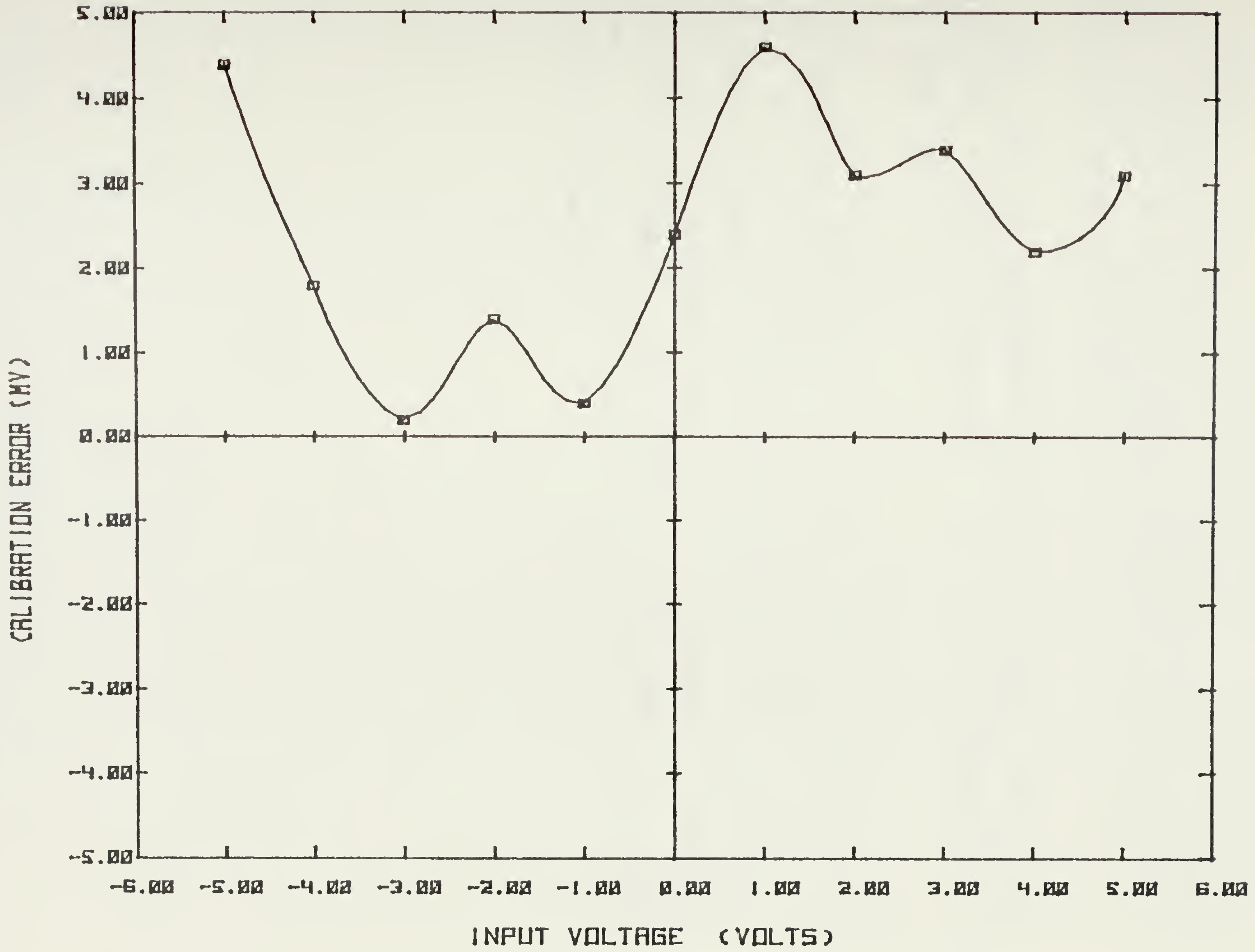


FIGURE 7 - DC VOLTAGE CALIBRATION RESULTS

B. SINUSOIDAL SIGNAL RECONSTRUCTION

This test was designed to evaluate the system's ability to accurately acquire, store, and reconstruct a sinusoidal input signal of known amplitude and phase relationship to a reference sinusoidal signal.

The test was conducted using the simple operational amplifier circuit illustrated in Fig 8, representing a low-pass filter.

The gain and phase of the output signal relative to the input signal were measured by using the Ballantine true RMS meter and an AD-YU phase meter, respectively. These data were hand logged and plotted in Figs 9 and 10 for comparison with the gain and phase parameters extracted by the analysis algorithm discussed in section IV. A very high correlation between the extracted parameters and the analog measurements is clearly observable.

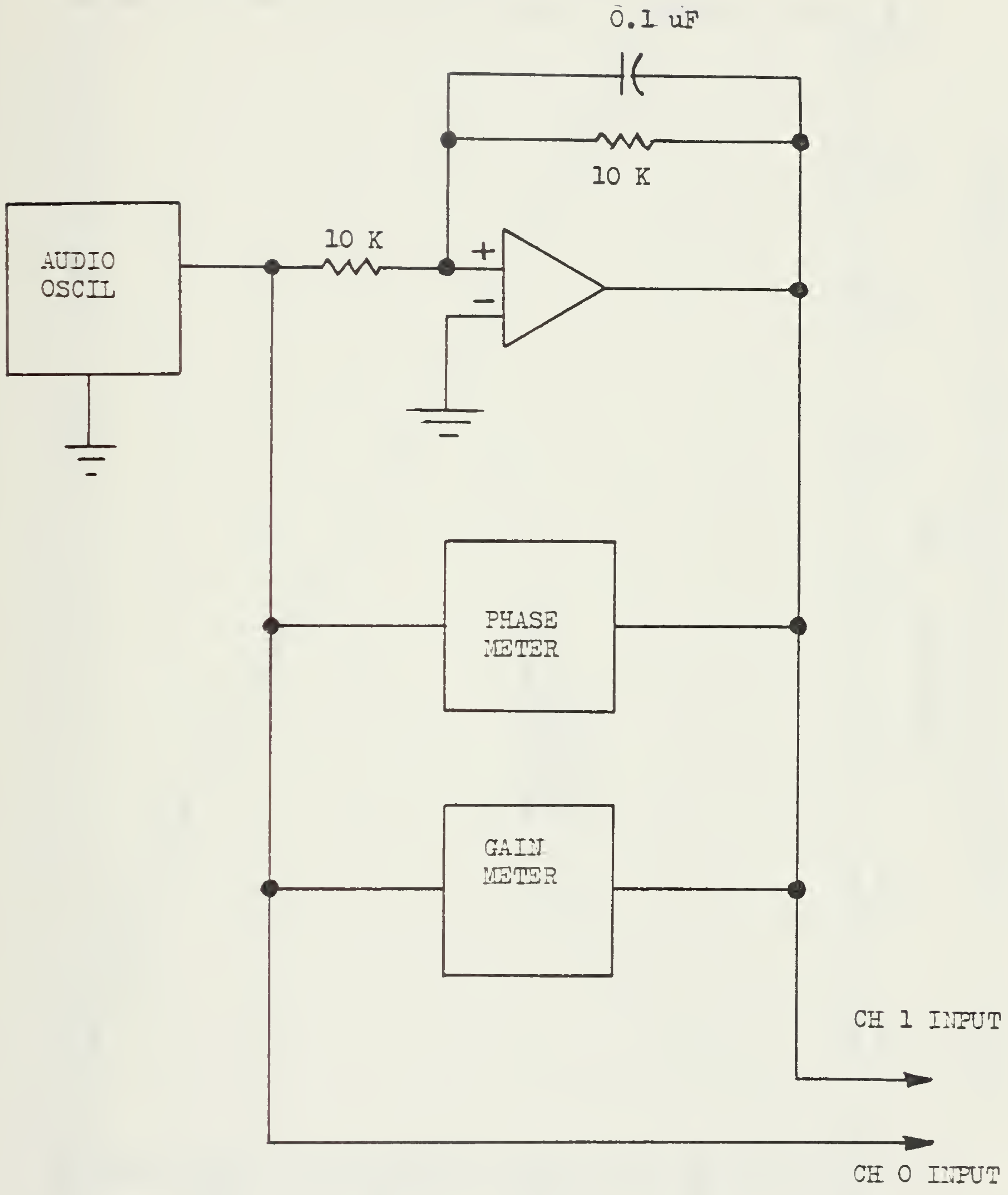


FIGURE 8 - SINUSOIDAL SIGNAL RECONSTRUCTION TEST CIRCUIT

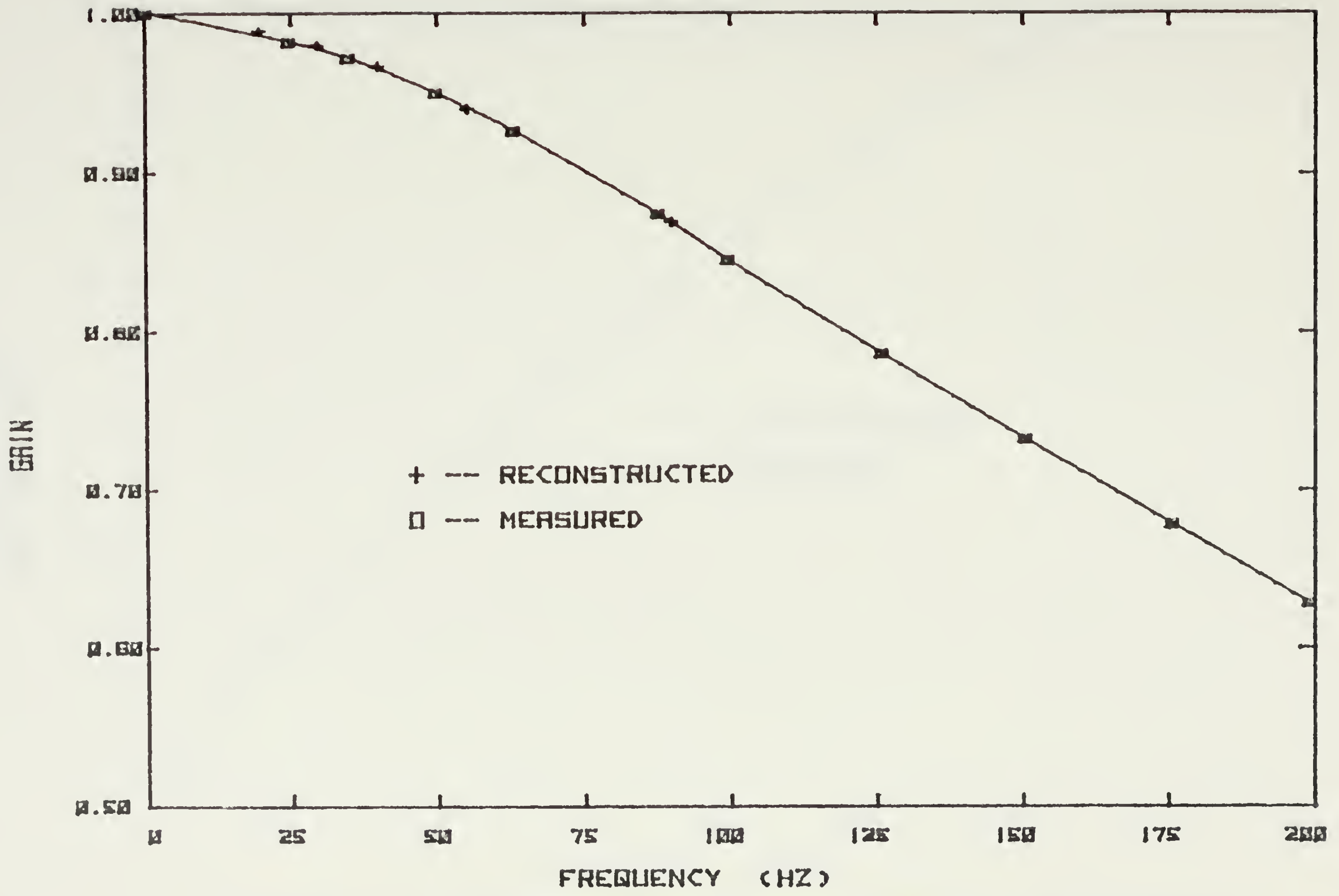


FIGURE 9 - SINUSOIDAL GAIN RECONSTRUCTION TEST RESULTS

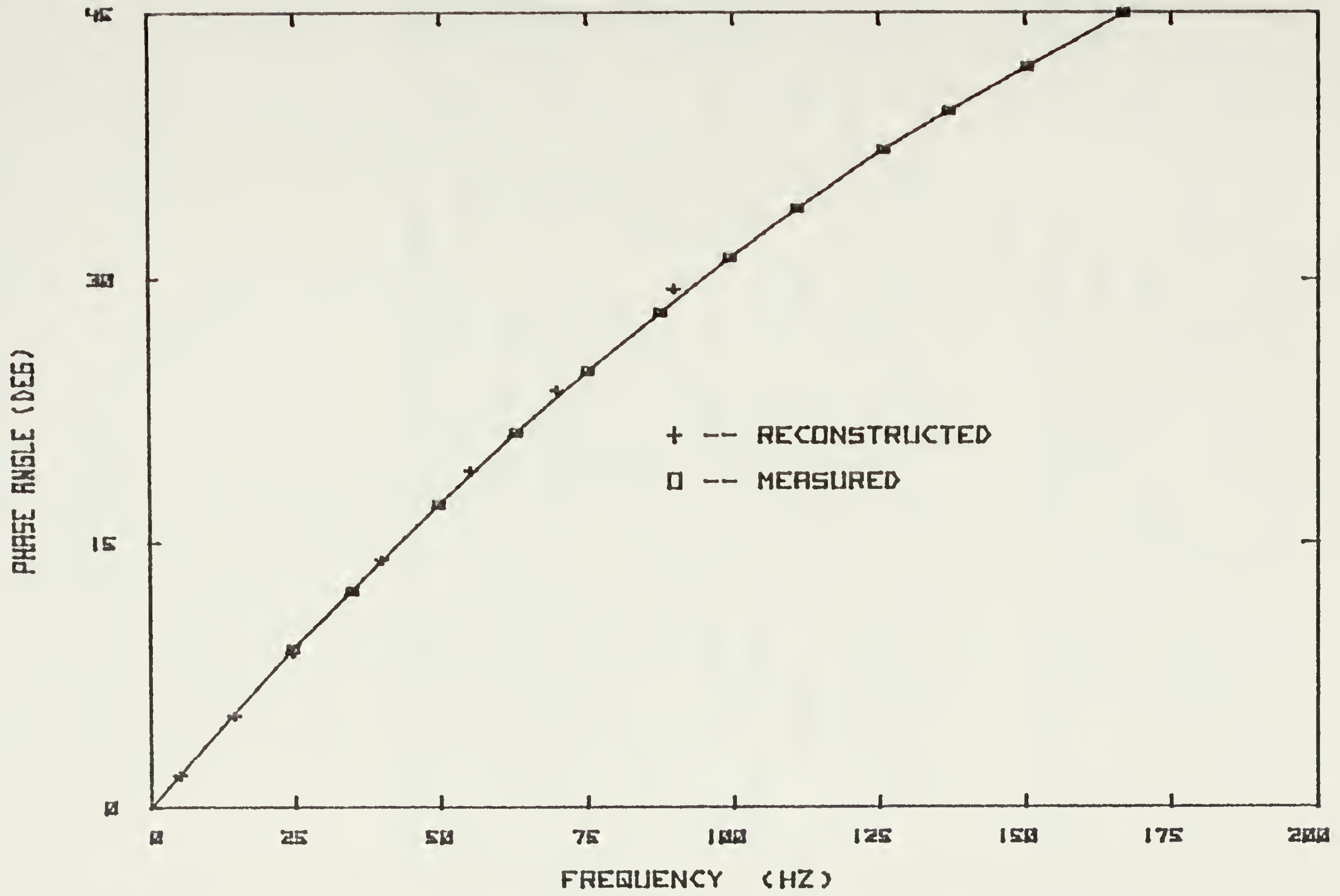


FIGURE 10 - SINUSOIDAL PHASE QUALIFICATION TEST RESULTS

C. SQUARE WAVE RESPONSE

This test was designed to evaluate the accuracy of the data acquisition system in reconstructing the higher harmonics contained within a periodic signal. Since a square wave is known to be composed of only odd harmonic components, with known relative amplitudes, the Fourier coefficients derived from this test were easily compared to theoretical results.

By injecting the square wave input into more than one A/D input channel simultaneously, a measurement of the interchannel sampling delay was possible through observation of the resulting phase shift between adjacent channels. Compensation for the artificially induced phase lag was accomplished within the BASIC data reduction algorithm. Referring to Fig 11, which illustrates the phase shift problem graphically, delta t was the amount of time required to switch from one A/D channel to the next and complete a conversion. The software steps for the switching process amounted to 74.5 micro-seconds of apparent phase lag. By adding this value to the time term within the reduction algorithm, the phase shift problem was nearly eliminated.

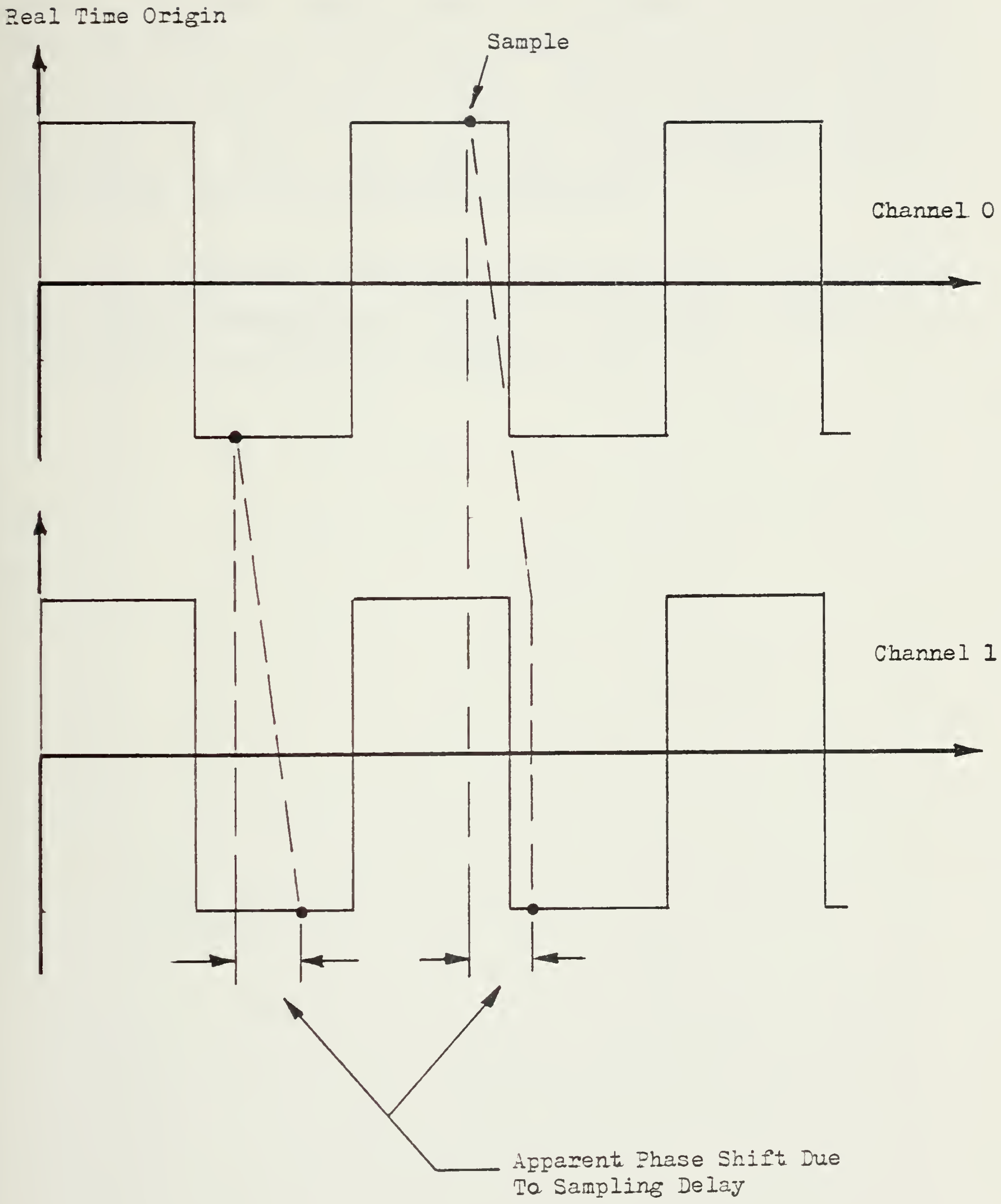


FIGURE 11 - PHASE ERROR DUE TO INTERCHANNEL SAMPLING LAG

The results of the harmonic reconstruction test are shown in Fig 12, which compares the extracted harmonic content of the square wave as produced by the REDUCE routine, with the theoretical expected values. The test was actually performed for several input frequencies ranging from 5 Hz to over 100 Hz, however, the resulting harmonic spectrum is shown only for the 10 Hz signal so as to illustrate as many harmonics as possible.

For comparison purposes, the phase shift realized with and without compensation within the analysis program are plotted as a function of frequency in Fig 13.

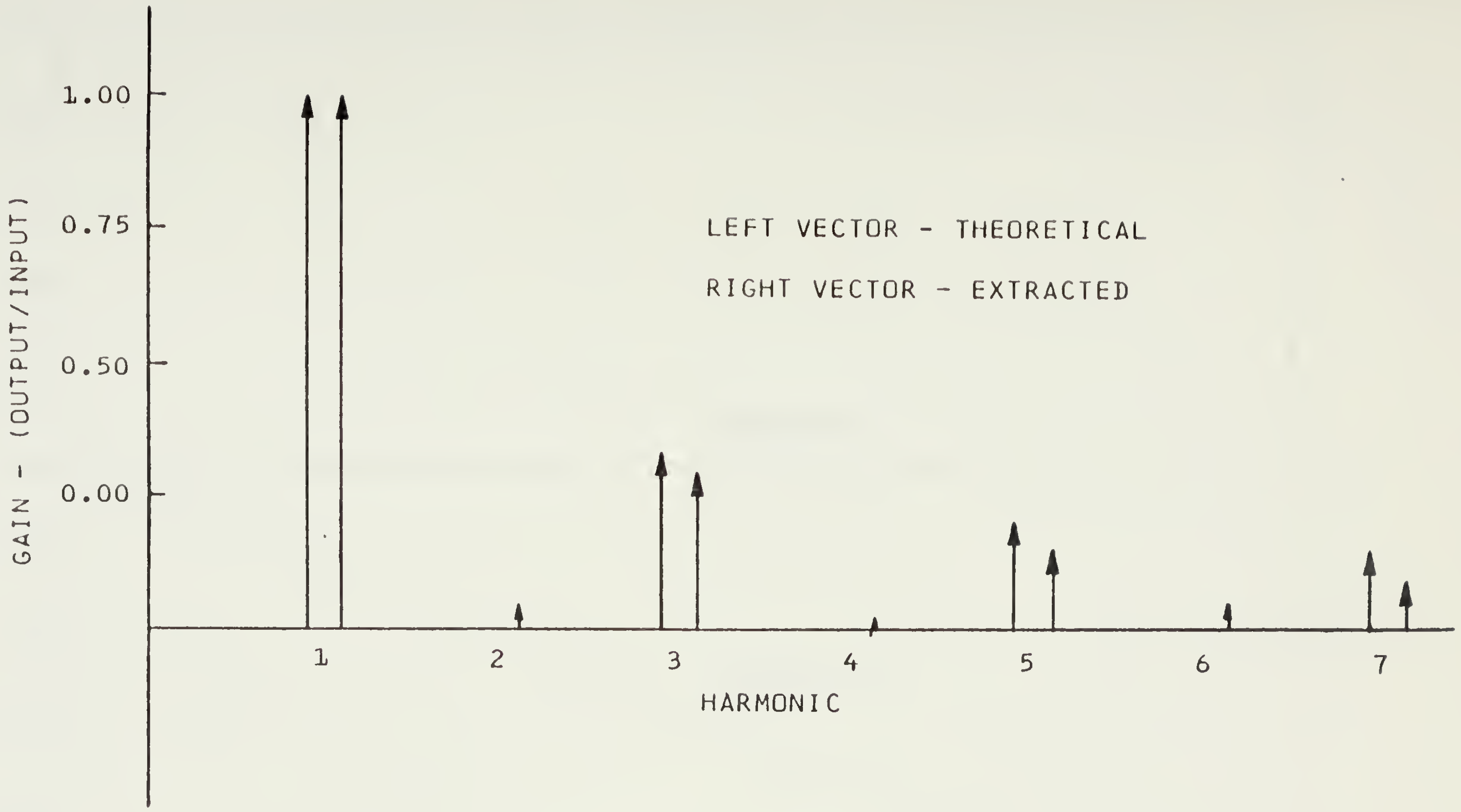


FIGURE 12 - SQUARE WAVE RECONSTRUCTION HARMONIC SPECTRUM

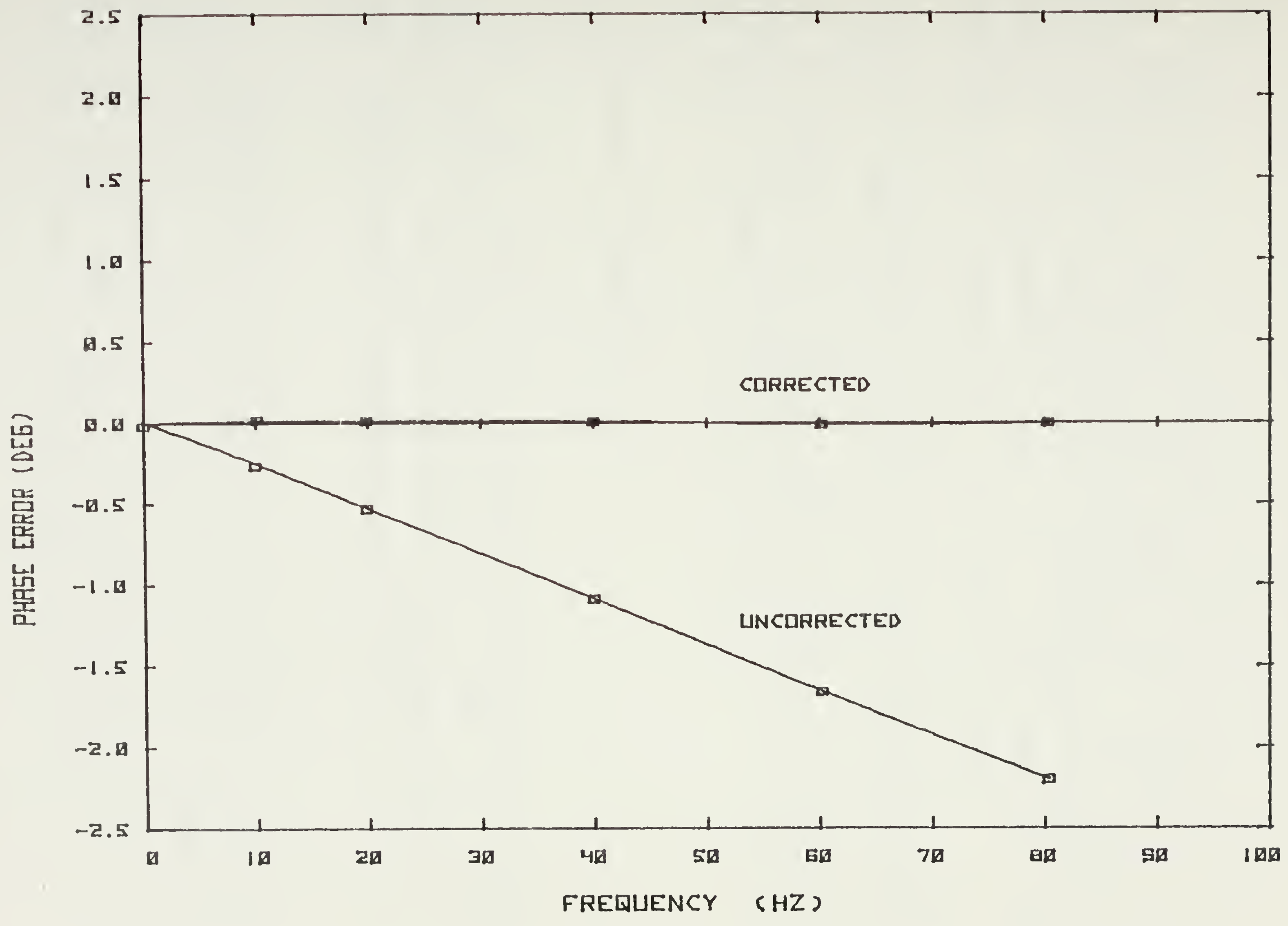


FIGURE 13 - EFFECT OF COMPENSATION ON INDUCED PHASE ERROR

VI. SYSTEM APPLICATION

Subsequent to the qualification tests and refinement of the reduction algorithm, the system was applied to the actual experimental environment for which it was intended. The system was integrated into the CCR airfoil experimental set-up as illustrated in Fig 14. This phase of the development was conducted for two important reasons:

* Evaluate the performance of the system under actual laboratory conditions in search of further improvment areas.

* Examine the Coanda sheet pressure profile with respect to phase and amplitude while sinusoidally modulating the plenum pressure of the airfoil section.

A. OPERATING CONDITIONS

The wind tunnel was configured to operate with steady flow during this initial evaluation run. Only the plenum pressure of the airfoil section was modulated sinusoidally with various driving frequencies ranging from 3.7 Hz to 13.7 Hz.

Previous work, presented in Refs 7 and 8, produced measurements of the Coanda sheet pressure profile using data from a true RMS meter. These data were hand logged and plotted. A measurement of the phase relationship was not possible using this technique, as the phase meter was inaccurate in the low frequency range investigated.

Digital data acquisition, therefore, provided the first opportunity for observing the phase shift between the driving force and the pressure reaction on the surface of the airfoil. Included in Appendix F is the CONTROL file used in this experimental run. 600 datum points were recorded at 5-millisecond intervals for each analog channel. The channels sampled were:

1. Ch 0.....Plenum reference pressure
2. Ch 1.....Scanivalve pressure (channels 10 thru 17)
3. Ch 2.....Hot wire annemometer

At each frequency, the Scanivalve was cycled along each of the indicated channels which corresponded to stations 23 through 30 of the airfoil. The actual logging of the more than 86,000 data points required approximately 45 minutes, of which approximately 35 minutes were devoted to effecting adjustment of the tunnel operating conditions and driving frequency.

Figures 15 through 20 show the graphical results of the data reduction which followed. Credibility is lent to the results by the close correlation achieved with the previous investigative efforts, and the consistency displayed among results of individual runs.

The graphical results of the phase extraction process are presented for documentary purposes in Figs 21 through 26. It was not within the scope of this work to analyze in detail the aerodynamics of the CCR. Therefore, the reader is directed to refs. 8 and 11 for more explicit information regarding the CCR analysis.

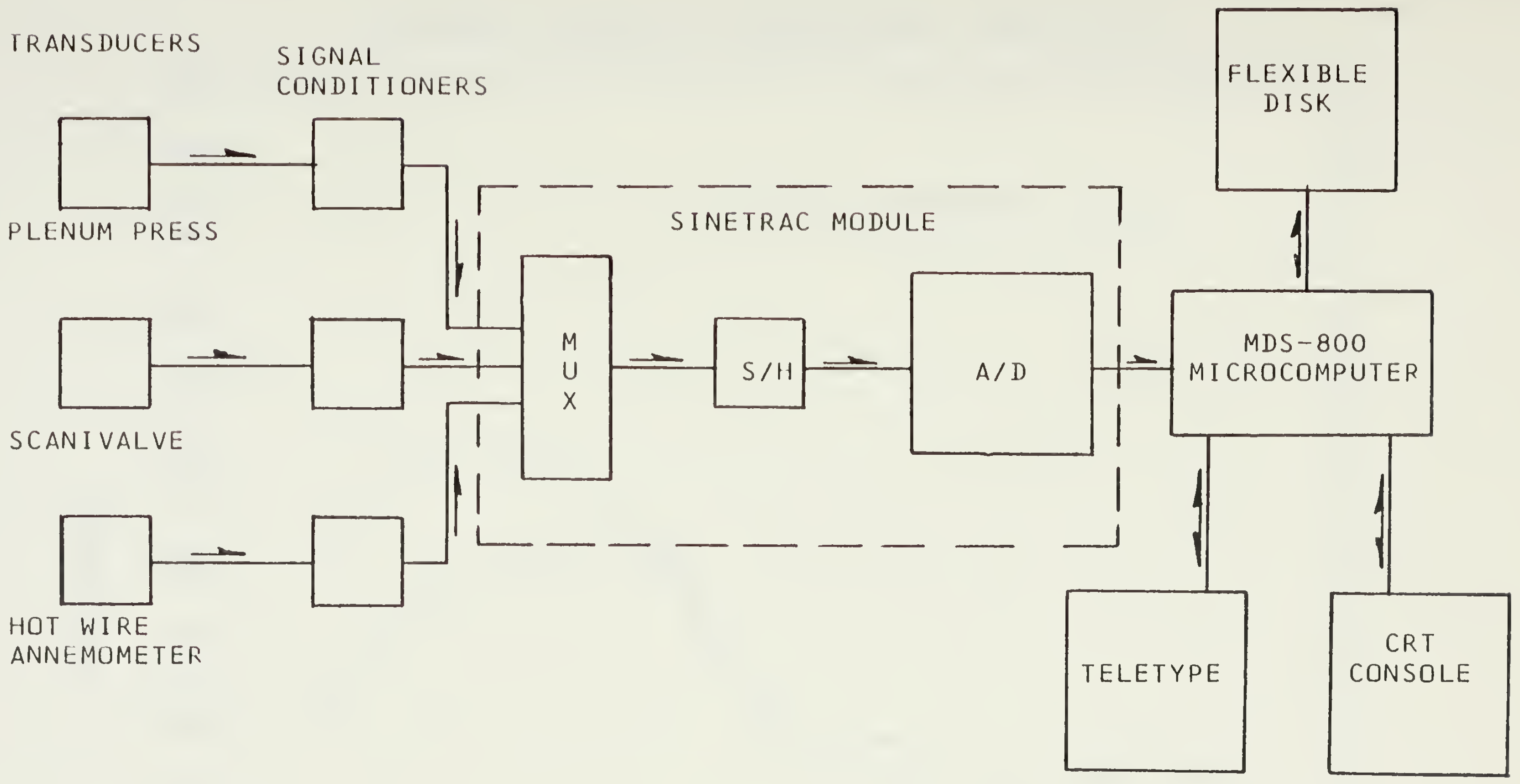


FIGURE 14 - SYSTEM APPLICATION CONFIGURATION

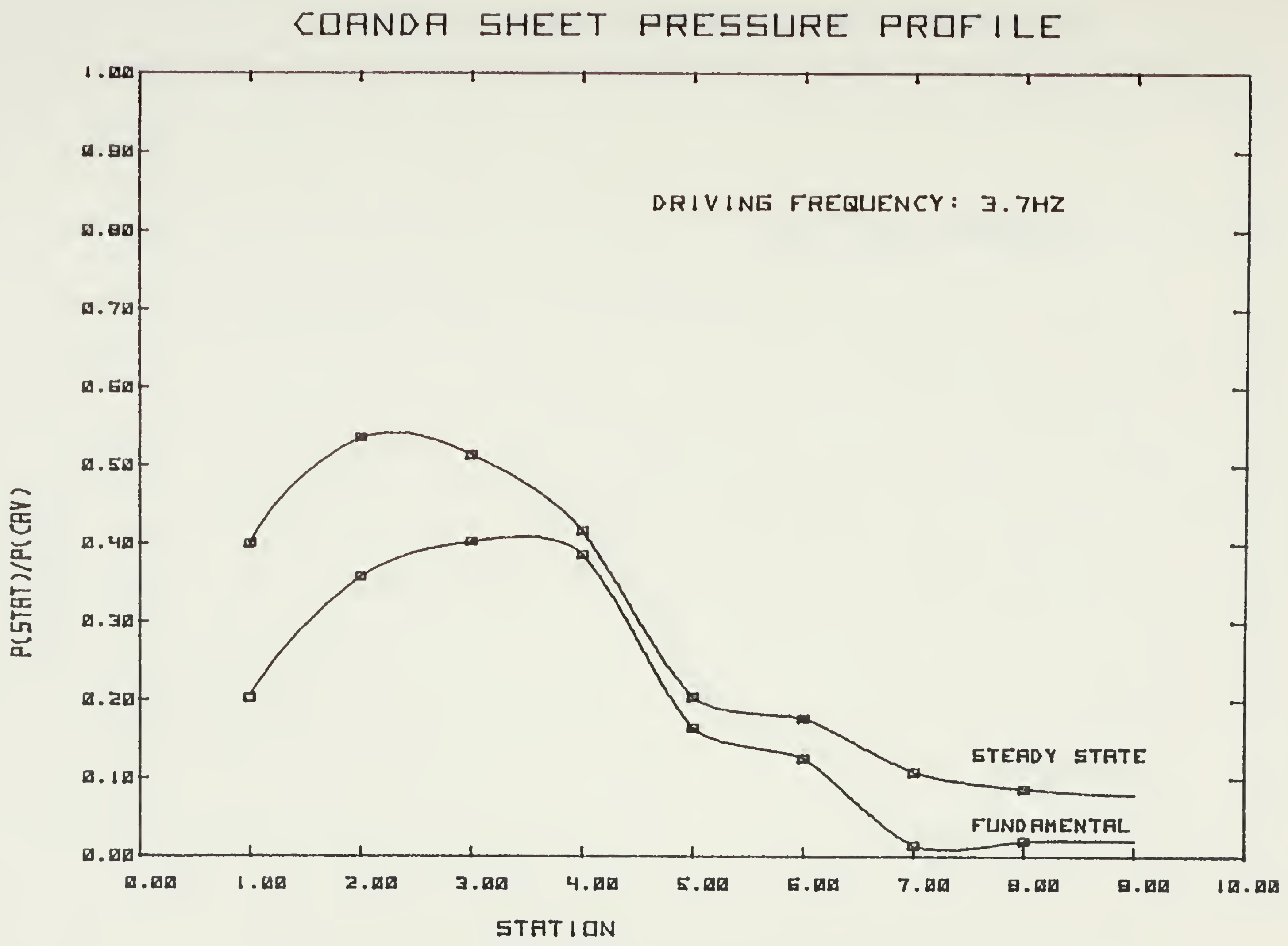


FIGURE 15 - FUNDAMENTAL MODE COANDA SHEET PRESSURE PROFILE (3.7 HZ)

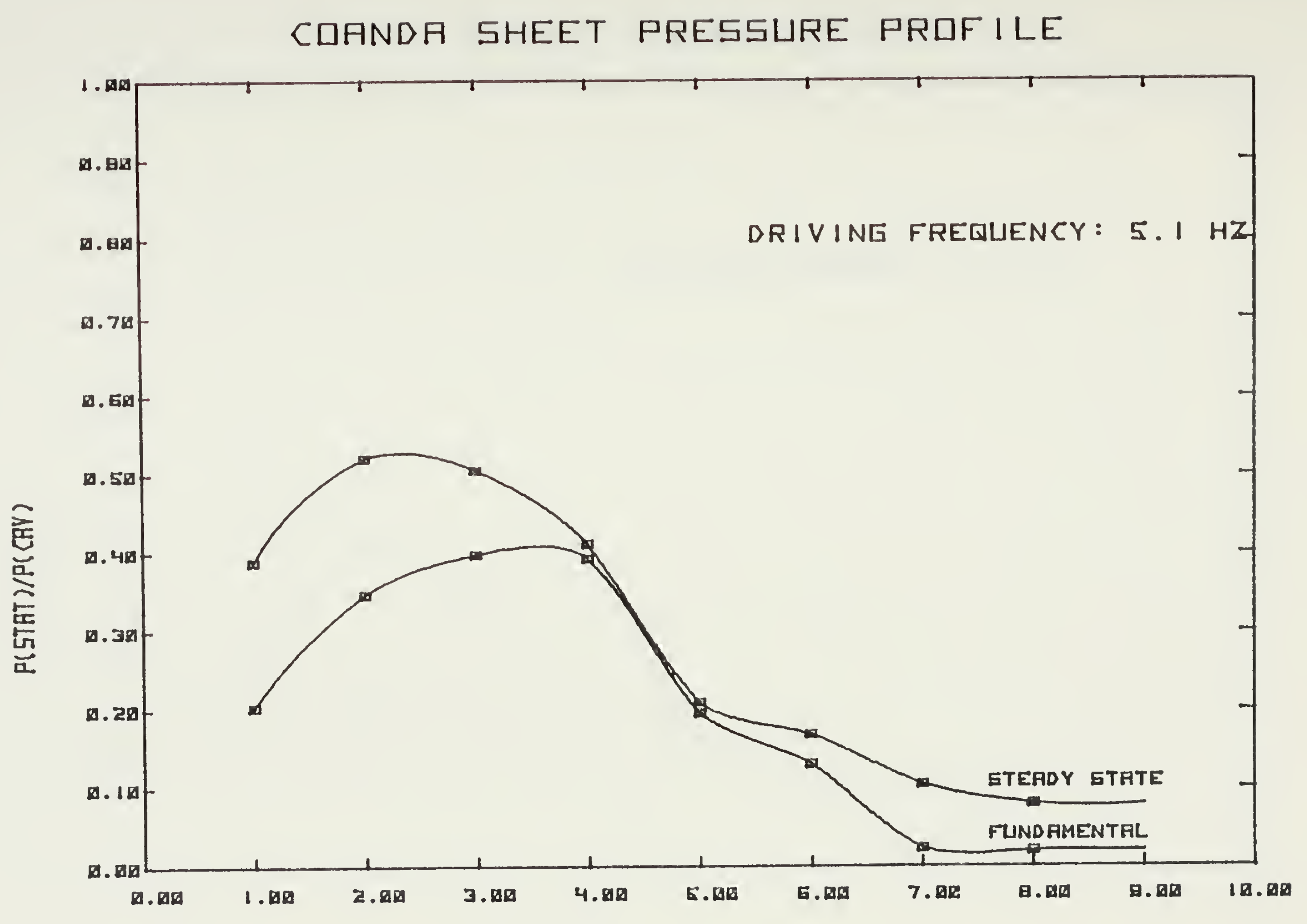


FIGURE 16 - FUNDAMENTAL MODE COANDA SHEET PRESSURE PROFILE (5.1 HZ)

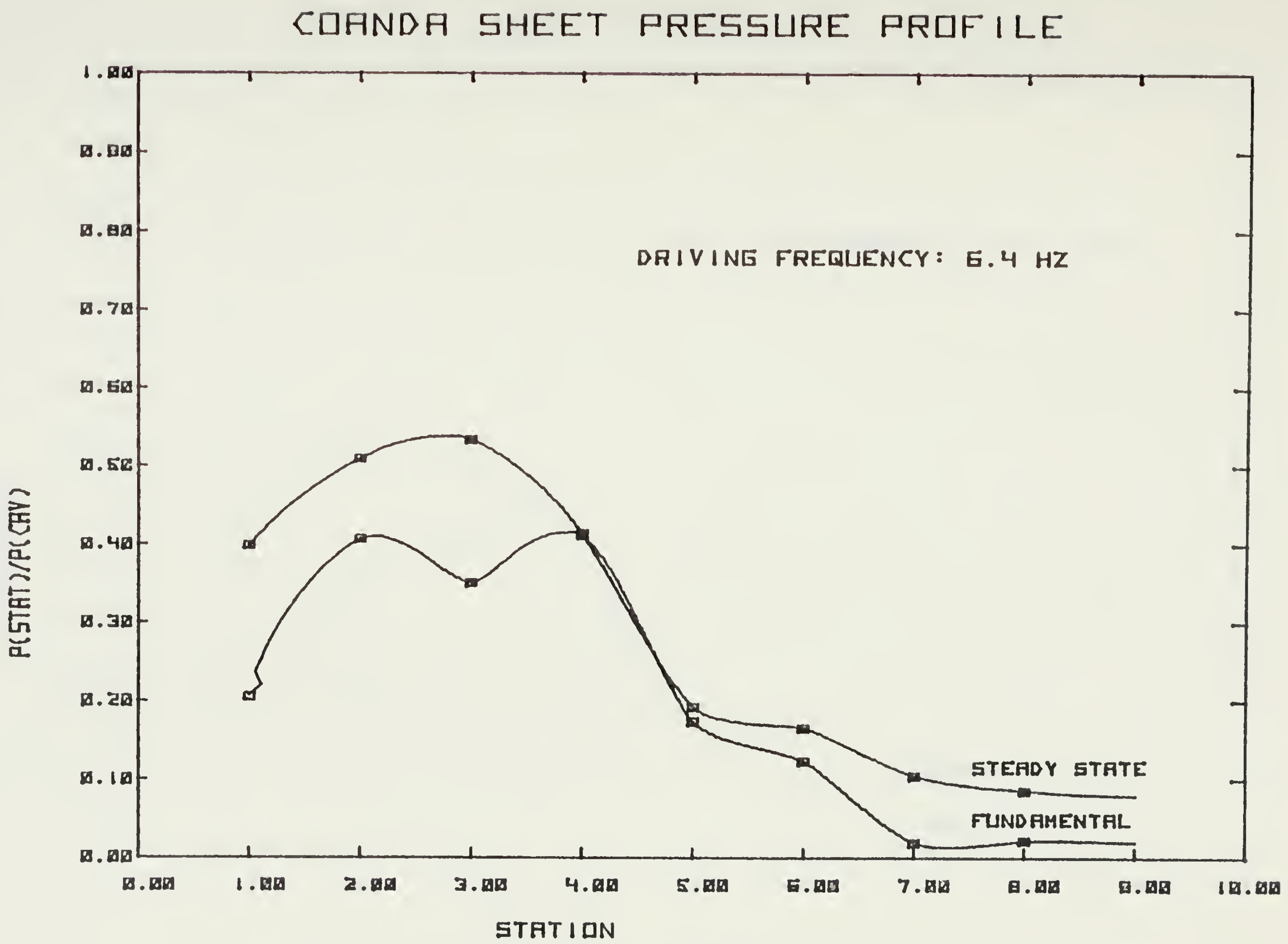


FIGURE 17 - FUNDAMENTAL MODE COANDA SHEET PRESSURE PROFILE (6.4 HZ)

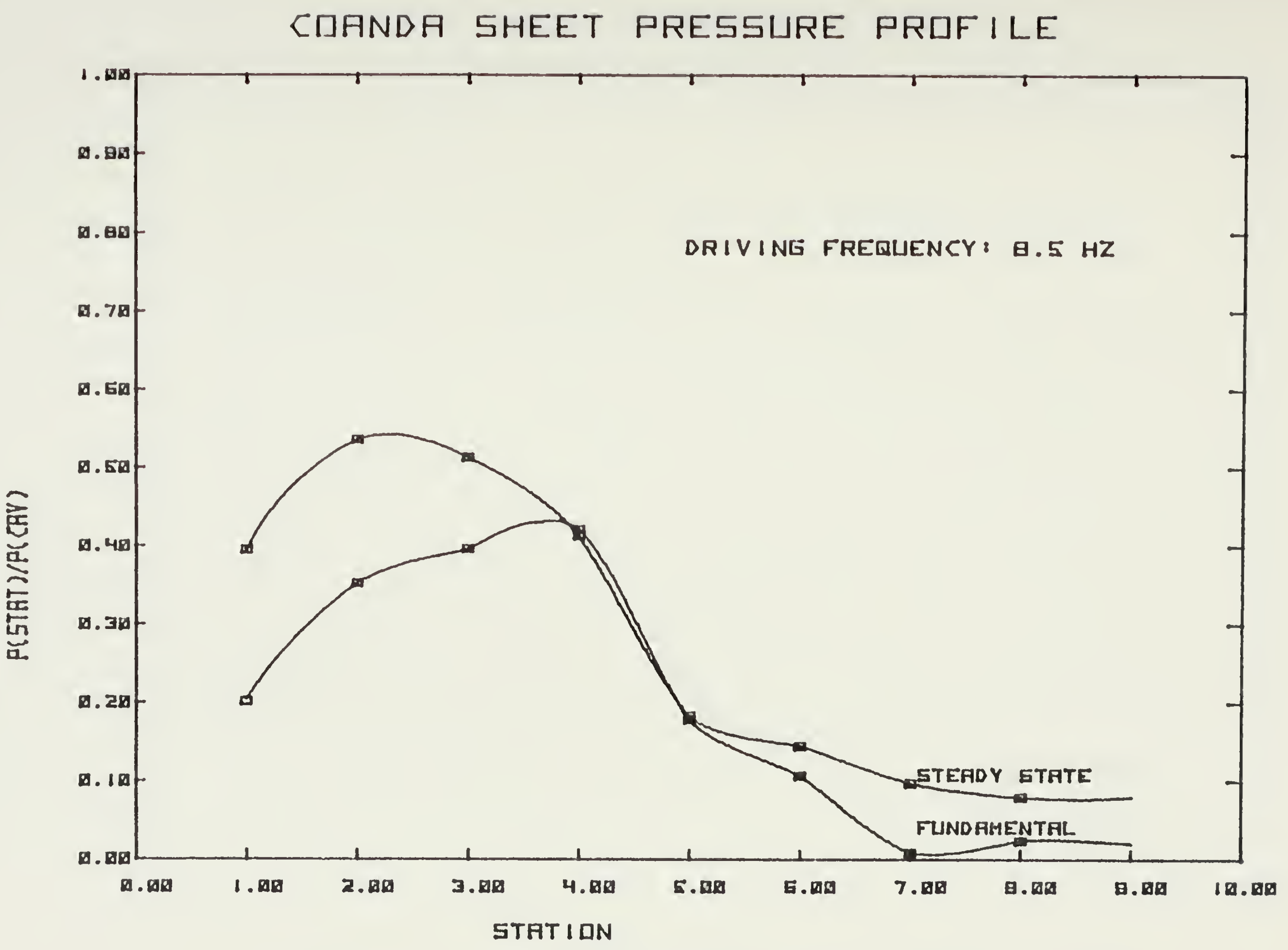


FIGURE 18 - FUNDAMENTAL MODE COANDA SHEEP PRESSURE PROFILE (8.5 HZ)

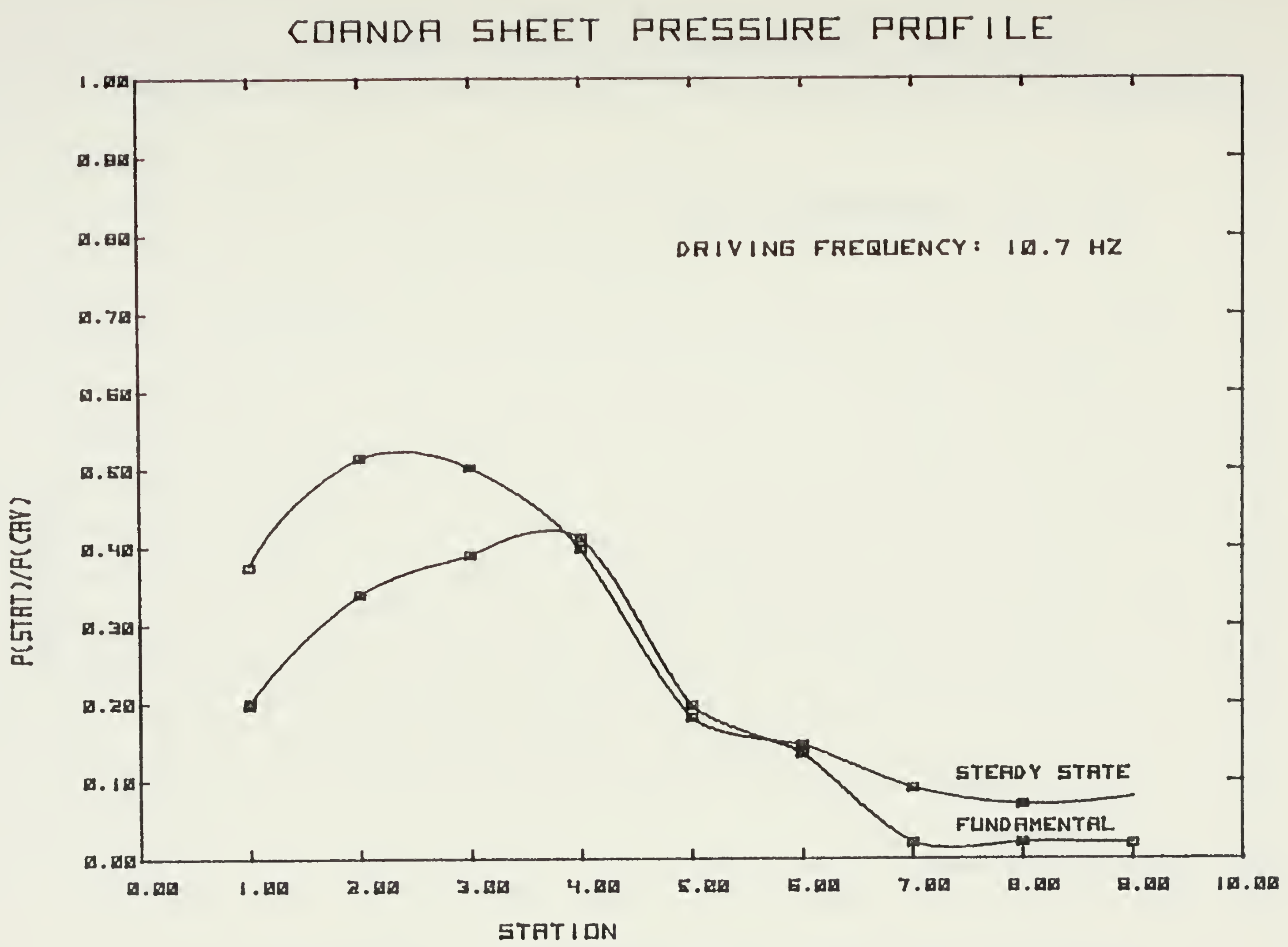


FIGURE 19 - FUNDAMENTAL MODE COANDA SHEET PRESSURE PROFILE (10.7 HZ)

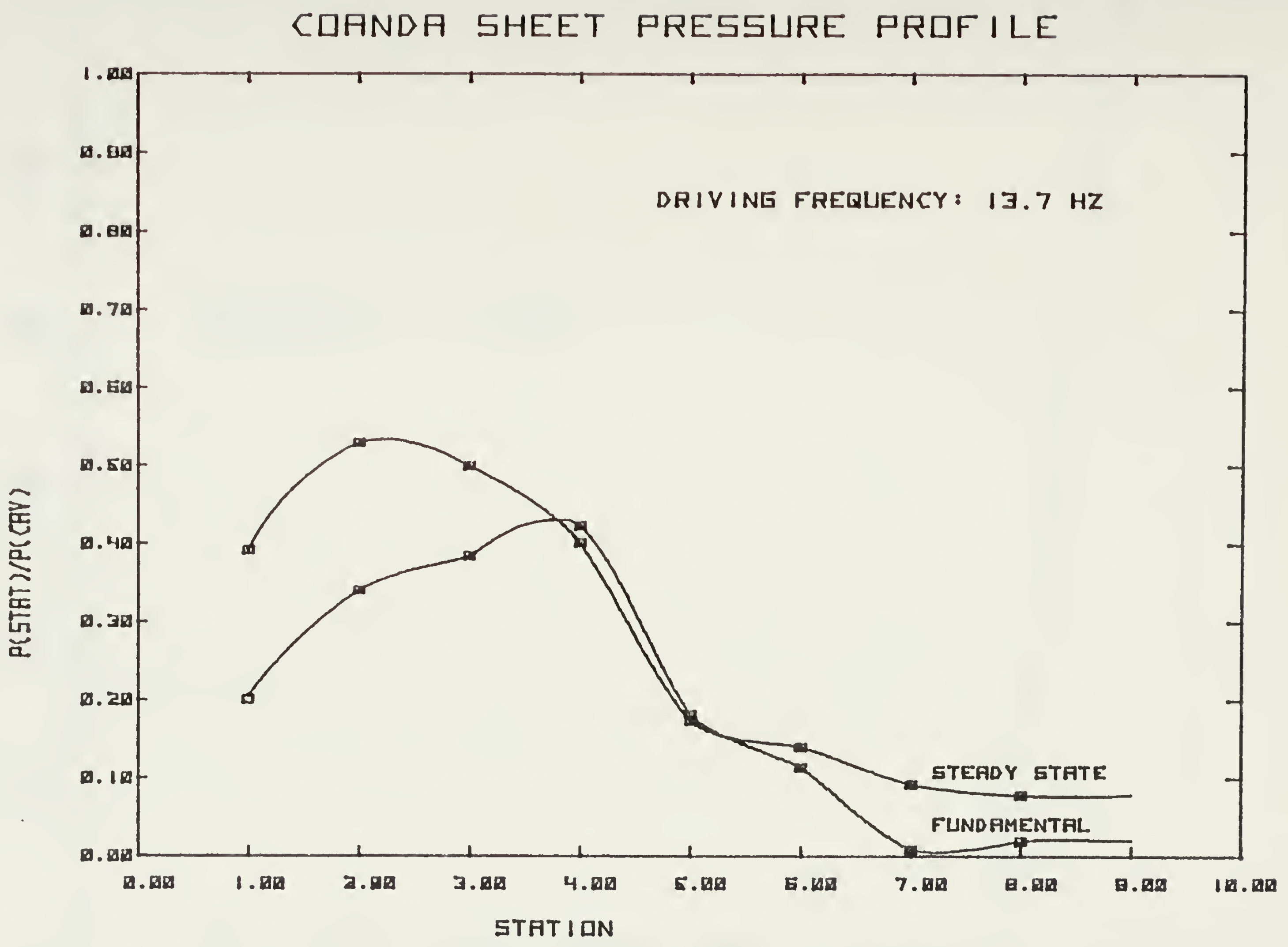


FIGURE 20 - FUNDAMENTAL MODE COANDA SHEET PRESSURE PROFILE (13.7 HZ)

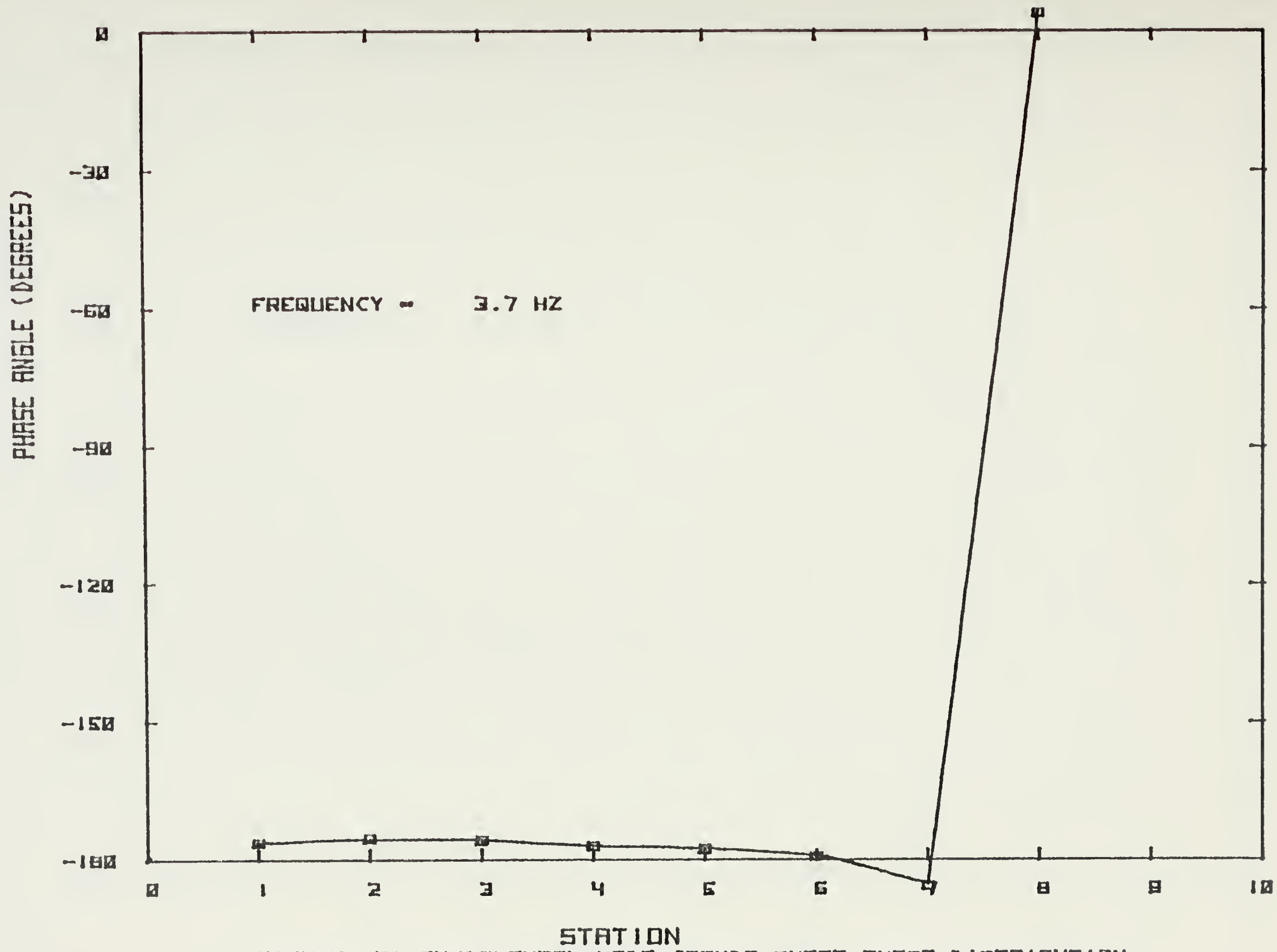


FIGURE 21 FUNDAMENTAL MODE COANDA SHEET PHASE DISTRIBUTION

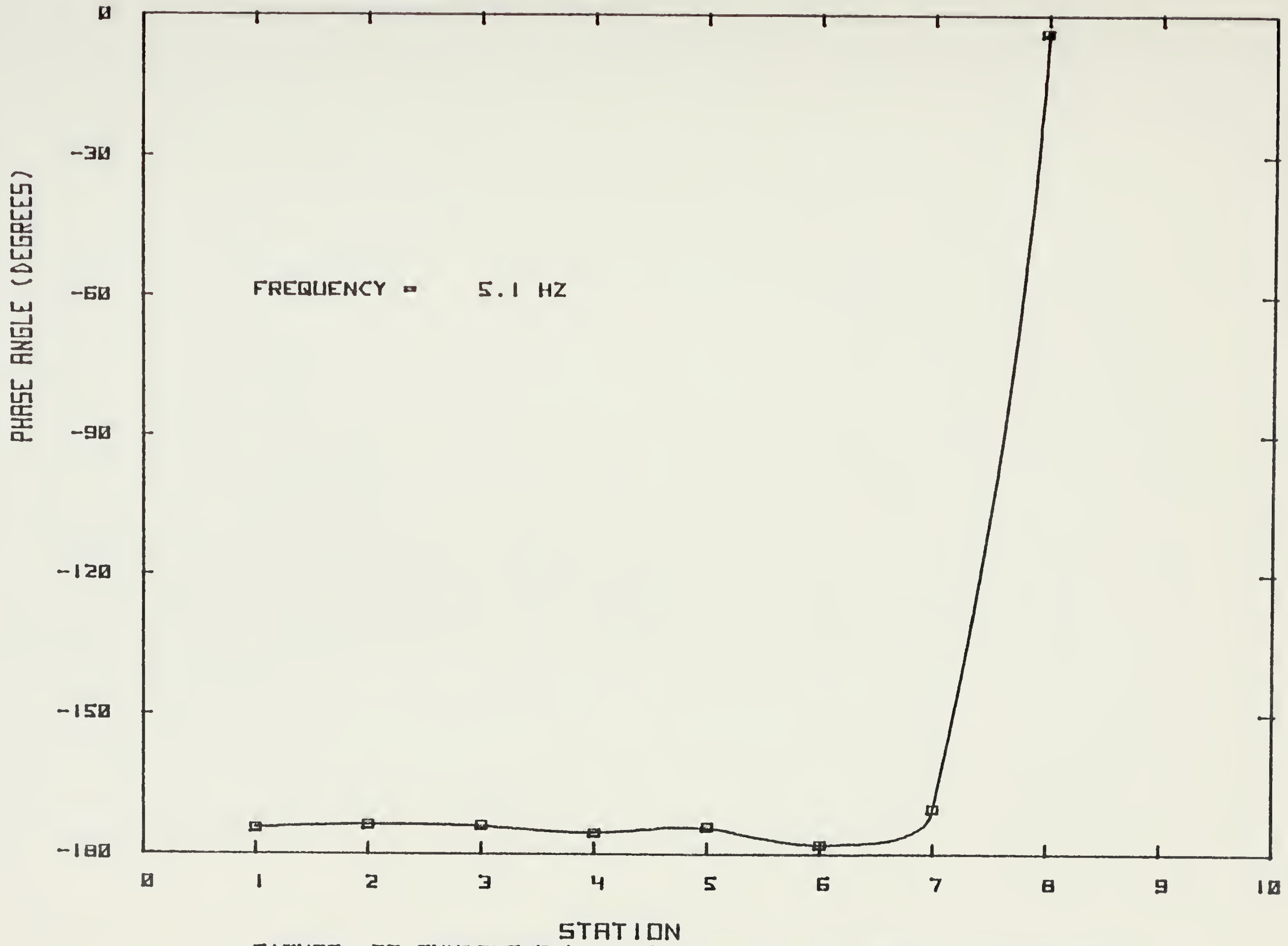


FIGURE 22 FUNDAMENTAL MODE COANDA SHEET PHASE DISTRIBUTION

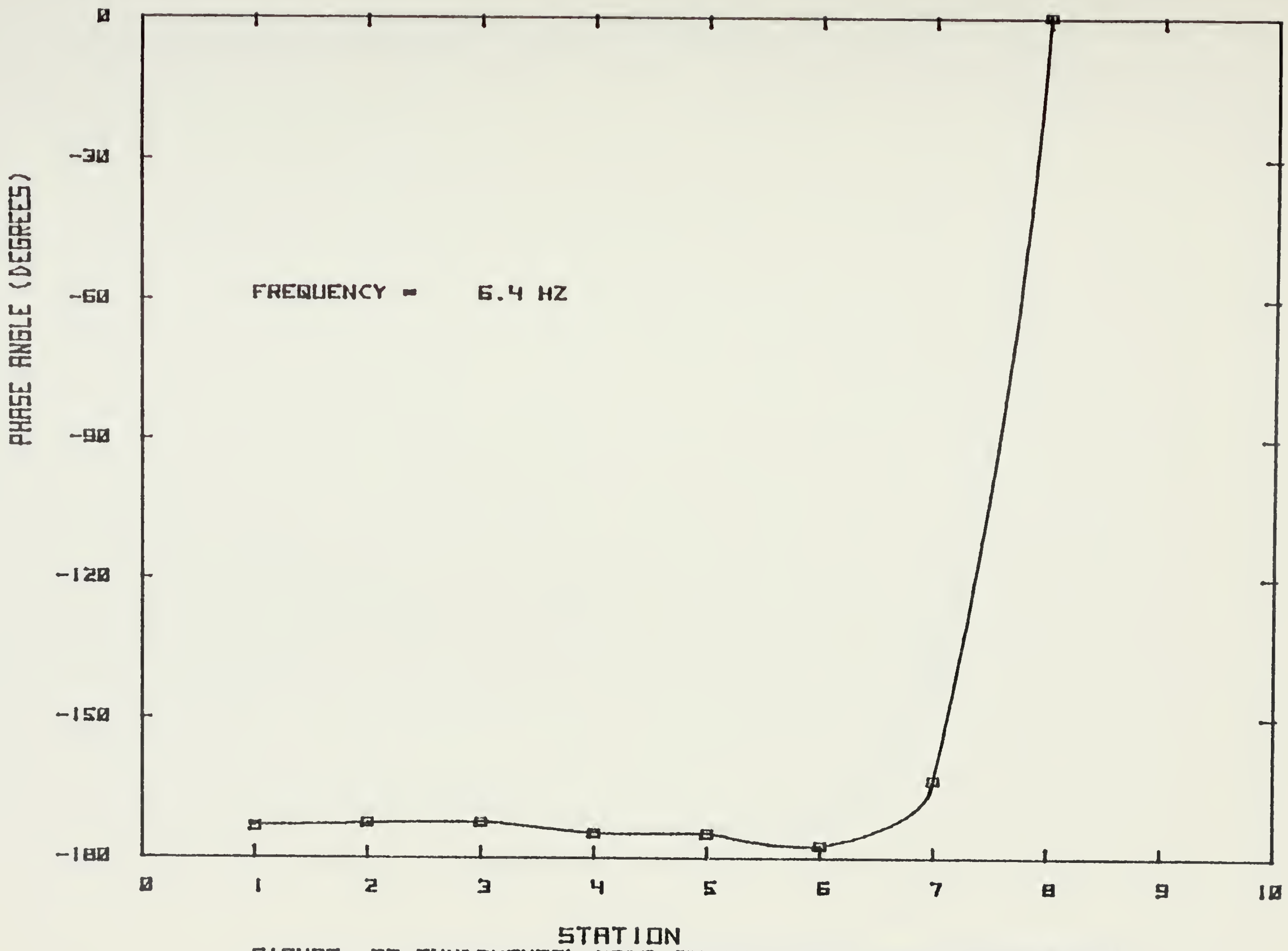


FIGURE 23 FUNDAMENTAL MODE COANDA SHEET PHASE DISTRIBUTION

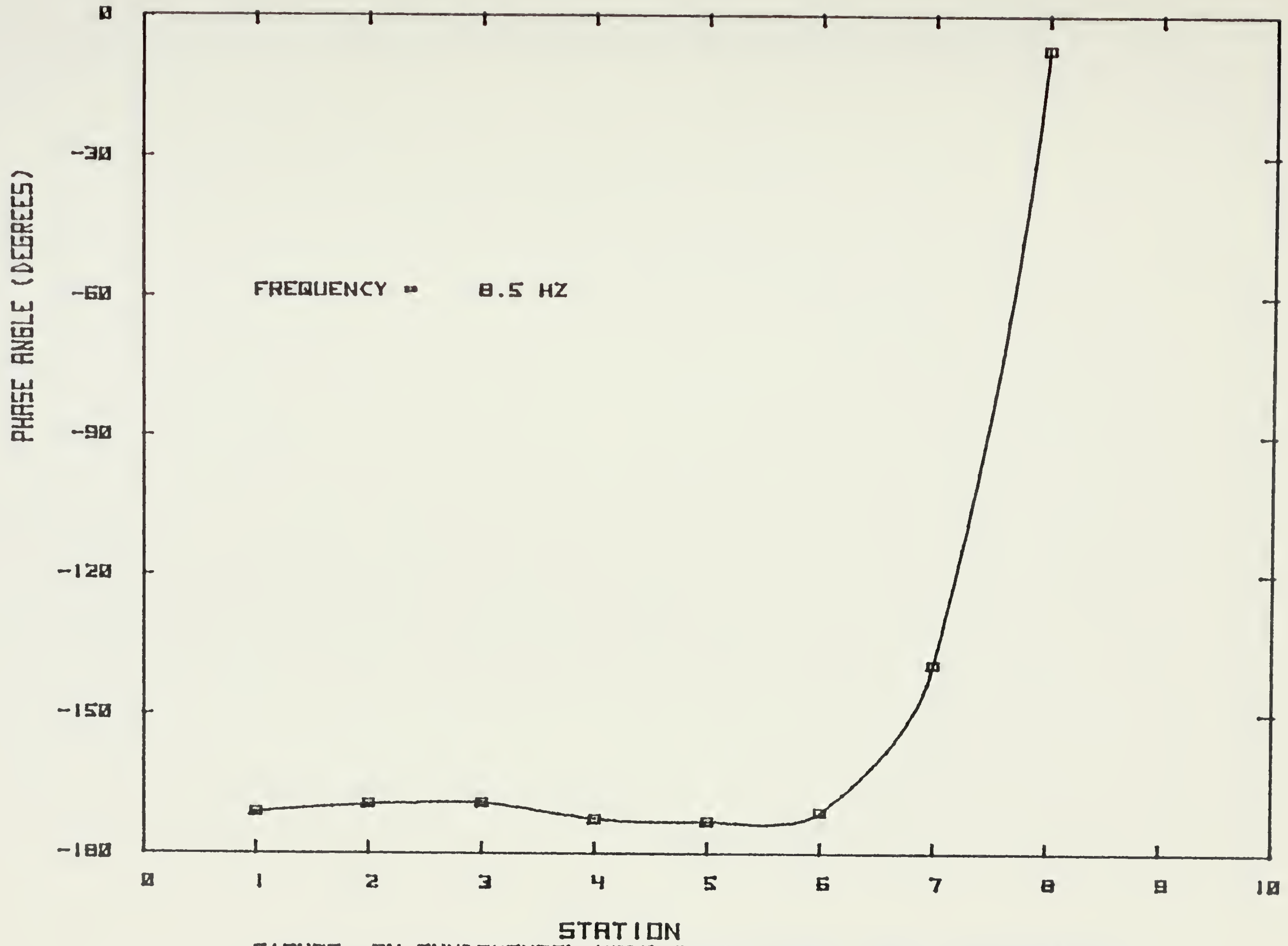


FIGURE 24 FUNDAMENTAL MODE COANDA SHEET PHASE DISTRIBUTION

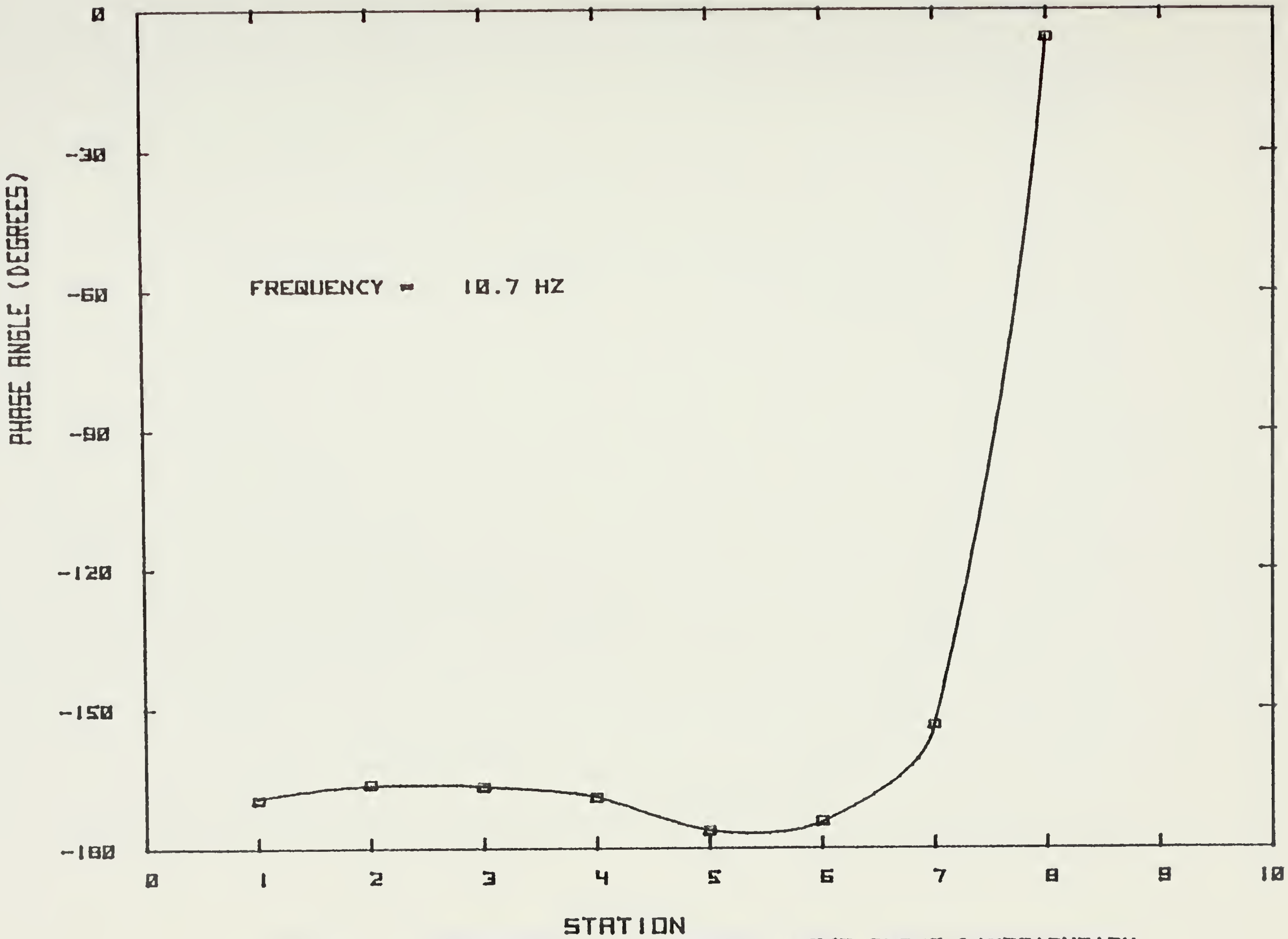


FIGURE 25 FUNDAMENTAL MODE COANDA SHEET PHASE DISTRIBUTION

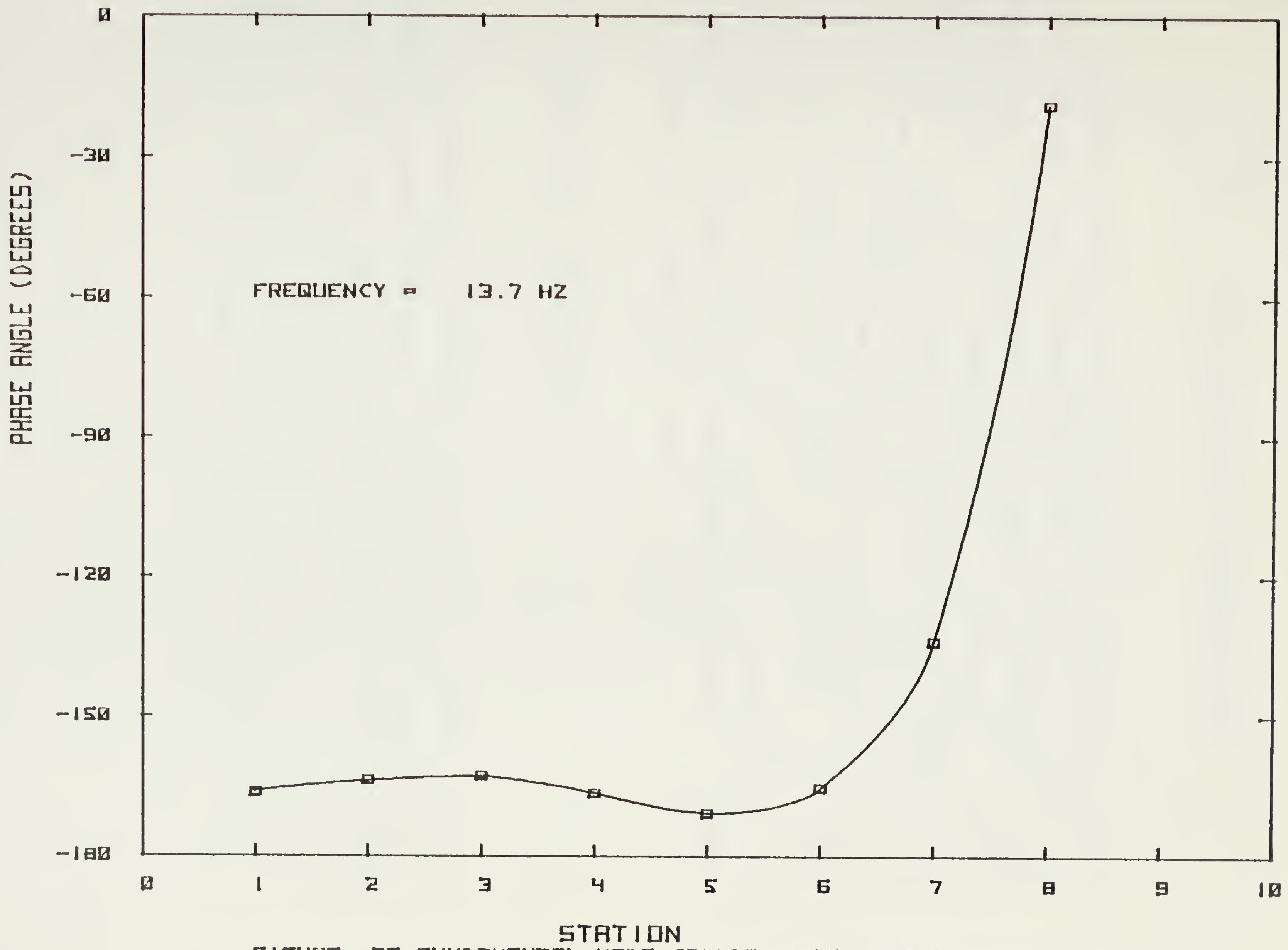


FIGURE 26 FUNDAMENTAL MODE COANDA SHEET PHASE DISTRIBUTION

VII. CONCLUSIONS AND RECOMMENDATIONS

During the course of the acquisition system development, modifications were constantly made with the intent of improving the performance or operator interface. System qualification and implementation disclosed several additional areas in need of improvement and, based on the experienced gained up to the time of this writing, the upgrade items discussed in this section are believed to be worthy of inclusion in any further development or future generations of the subject system. In some cases alternative solutions to existing shortcomings are presented, taking into consideration current industry developments in compatible hardware modules.

A. INTERCHANNEL SAMPLING LAG

As previously discussed, the finite amount of time required for the processor to switch from one analog channel to the next, and make a conversion, caused an apparent phase shift in the resulting reconstruction of two or more adjacent channel signals. This problem was partially overcome by time adjustments within the reduction algorithm. However, inaccuracies were still attributable to this problem.

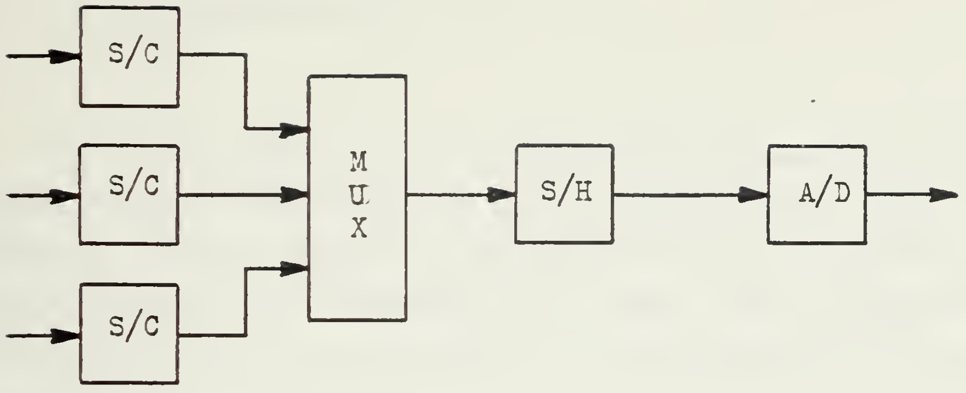
Two additional approaches to the problem remain:

1. <u>Interchannel Delay</u>

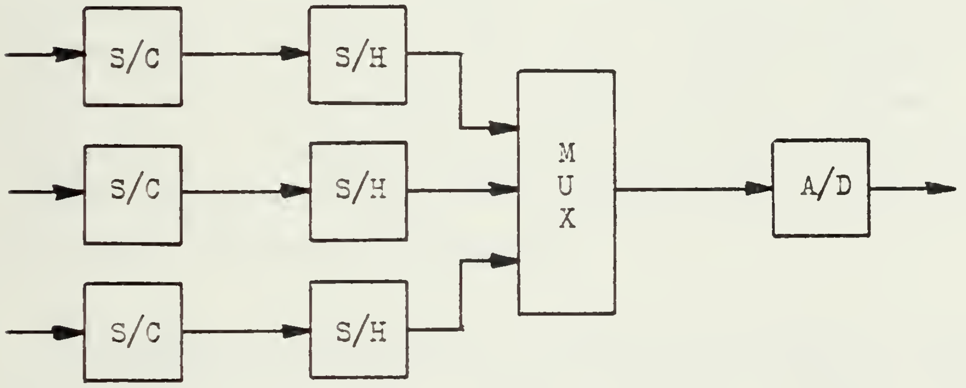
Effecting a reduction in the interchannel delay time, thereby reducing the relative influence of the lag, is one possible solution. This could be accomplished by the inclusion of a DMA module within the MDS mainframe to augment the capabilities of the SINETRAC-800. This solution although not absolute, would achieve a decrease of the interchannel delay from 74.5 microseconds to 15 microseconds.

2. <u>Individual Sample and Hold Circuitry</u>

The system as described herein contained only one sample and hold circuit which was located downstream of the multiplexor unit. Since each channel shared the same sample and hold circuit,, it was impossible to strobe all channels simultaneously. Inclusion of an independent sample and hold circuit element dedicated to each analog channel input would eliminate the phase shift problem completely, since all channels would be sampled at precisely the same instant when triggered by a common source. The sample and hold circuit would maintain the DC level until the A/D was able to poll the individual inputs through the multiplexor. This concept is illustrated in Fig 27.



Single Sample and Hold



Multiple Sample and Hold

FIGURE - 27 SINGLE VS MULTIPLE SAMPLE AND HOLD CONCEPT

B. SYSTEM ACQUISITION SPEED

As presented, the acquisition system was limited to an absolute maximum sampling rate of 500 Hz for more than one analog channel input. This rate could be improved for a few more channels to a maximum of 1 KHz with modifications to the timer interrupt and use of the program interrupt mode on the SINETRAC-800.

For any significant improvement, however, the actual start of scan trigger would require alternate sourcing. The A/D board provided for an on-board control of the scan clock or external triggering. A modification to the triggering of the scan clock could be effected with minimal additional circuitry of local design, utilizing a general purpose proto-typing circuit board for generation of a strobe or sensing of an external syncronization pulse. It is important to realize that any such design should attempt to retain software control over the sampling rate so as not to lose this flexibility feature.

Tremendous reductions in software could be realized with the addition of the Direct Memory Access module. This addition would increase the maximum scan rate attainable from .5 KHz to approximately 11 KHz for 6 channels or from 1 KHz to 33 KHz for 2 channels of input.

In short, the addition of a DMA module is highly recommended in consideration of the multiple improvements in system performance that it affords for a modest expenditure.

C. DATA REDUCTION

The concept of locally reducing the data has many advantages, and likewise disadvantages, which must be considered in future modifications to the system. The decision to locally reduce data was based upon two major factors. First, it was desired that the feasibility of local reduction on a microprocessor be investigated. Secondly, during the design stages the only data communications link available to the W.R. Church computer facility IBM-360 for remote processing was via Teletype speed (110 baud) modem. Anticipating the generation of 250,000 words of data each experimental session, transmission over the existing time-share system network was deemed unreasonable. Transfer of this volume of data would have required at best 7 hours real time, assuming minimal handshaking and system interruptions. The potential of generating several data diskettes during one experimental session renders a slow transmission rate link totally impractical. The CP/CMS system did not, at that time, exhibit the reliability necessary for such a link to be used effectively. At the time of this writing the computer center was completing the installation of communication links capable of 9600 baud. transmission rates. At this rate, a full diskette (250K bytes) could be transmitted in as few as 5 minutes. This capability would greatly enhance the computing power of the system, considering the increased sophistication of reduction techniques and output facilities (plotters, high speed printers, etc.) which would then be made available.

Should the autonomy of the system be an over-riding consideration, it is recommended that a high speed printer,

Digital to Analog (D/A) module and an X-Y plotter be included as suplementary system peripherals. The inclusion of an external mathematics module would further improve the system's computational speed and efficiency. Such a module, commercially available, would perform all floating-point mathematical operations (add, subtract, multiply and divide) in circuitry external to the 8080 microprocessor at approximately ten times the speed currently available. The addition of these modules and peripherals would upgrade the system into a completely independent, highly flexible data acquisition and computational device capable of a multitude of data logging or analytical tasks.

APPENDIX A

GLOSSARY

1. accuracy: The ability of a measurement system to determine the true level or state of a variable in terms according to standards of reference.

2. A/D: analog to digital (adjective or noun)

3. Alias: When varying signals are sampled at equally spaced intervals, two frequencies are considered to be aliases of one another if they cannot be distinguished from each other by an analysis of their equally spaced values.

4. ASCII: American Standard Code for Information Interchange. This is a seven-bit-plus-parity code established by the American National Standards Institute to achieve cpmpatibility between data services. Also called USASCII.

5. assembly: A listing which contains both source code and machine code.

6. BAUD: A data transmission rate expressed in BITs per second.

7. BIT: BInary digiT. A single unit of information in a binary word.

8. buffer: A group of memory locations used to store specific data (input data, constants, output data, etc.).

9. byte: An eight-BIT word which is processed as a single quantity.

10. CPU: Central Processing Unit. The area of the microprocessor which computes and sequences all logic and arithmetic functions.

11. CRT: Cathode Ray Tube - A television-like picture tube used in visual display terminals.

12. D/A: The inverse of the A/D process.

13. DMA: Direct Memory Access - a facility that permits I/O transfers directly into or out of memory without passing through the processor's general registers; either performed independently of the processor or on a cycle-stealing basis.

14. EPROM: erasable/programmable read only memory

15. Folding Frequency: The lowest frequency which is its own alias, or that which is one-half the sampling rate when samples are continuously made at equal intervals.

16. I/O: input/output

17. K: A suffix which indicates a group of 1024 (2^{10}) items as in '4K of memory' meaning 4096 memory locations.

18. Lag: A difference in time of occurrence between two events.

19. machine code: The BIT patterns actually used by the U-P in order to carry out its assigned logic functions.

20. MODEM: MOdulator DEModulator - an electronic device which modulates signals transmitted over communications circuits.

21. MUX: a multiplexing device

22. nibble: The upper or lower four BITs in one byte.

23. page: a 256 byte segment of memory

24. RAM: Random access memory. Volatile memory used for variable storage and data manipulation.

25. register: A storage location located in the CPU.

26. Resolution: The ability to determine signal differences in varying signals.

27. ROM: read only memory, non-volatile

28. Sample and Hold: A device for sampling the amplitude of a signal at a given time and holding that amplitude.

29. Sampling Theorem: Nyquist's result that equi-spaced data, with two or more points per cycle of highest frequency, allows reconstruction of band-limited functions.

30. software: The program which resides in the U-P's memory.

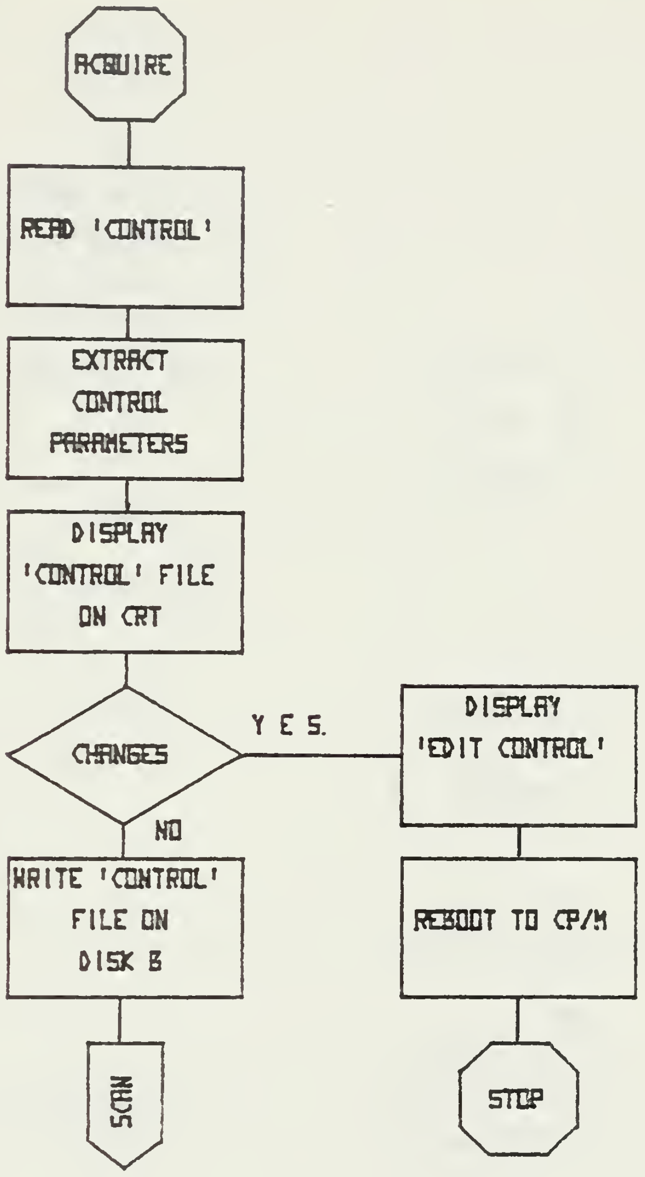
31. source code: The program written by the user.

32. U-P: microprocessor

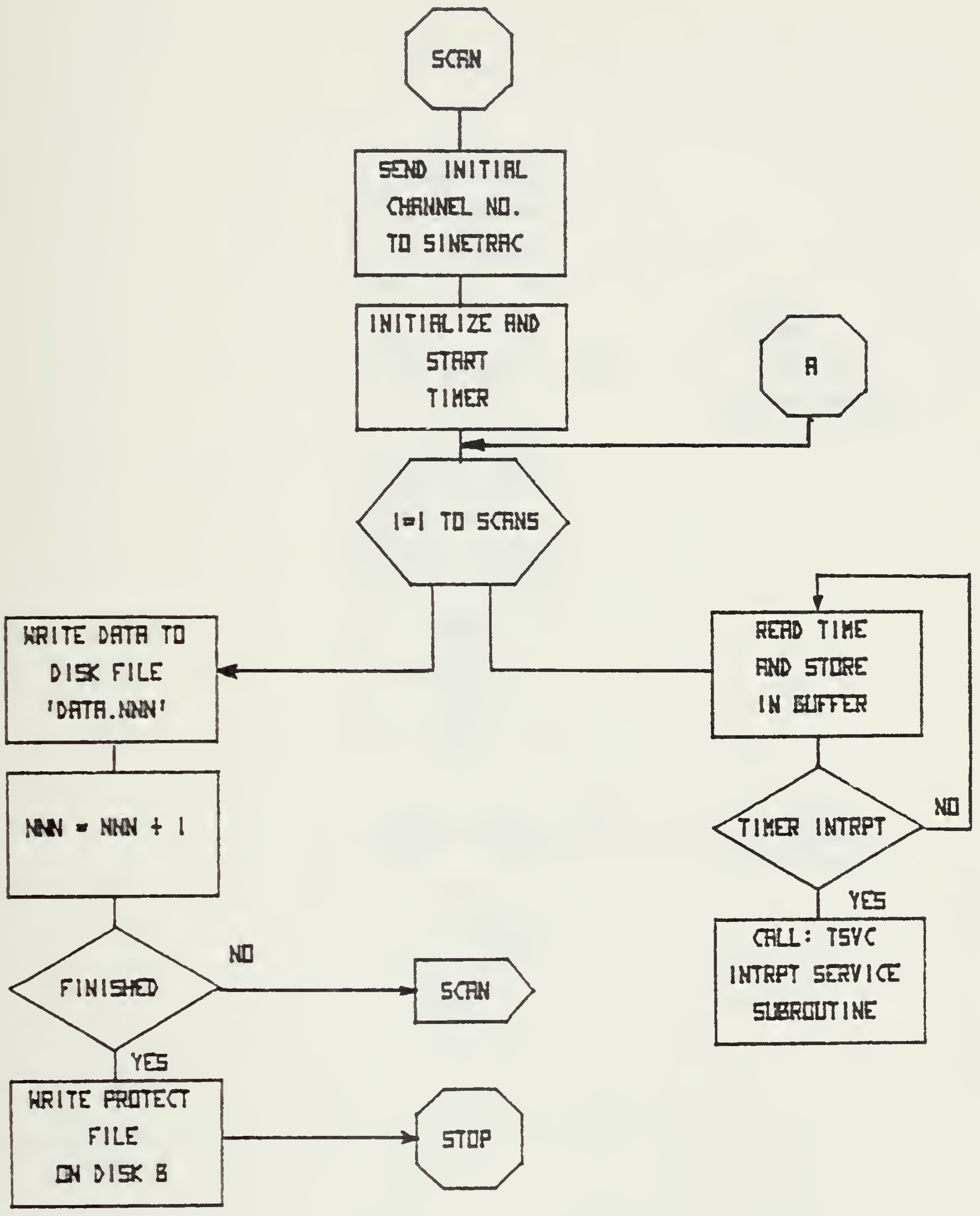
APPENDIX B

PROGRAM FLOW DIAGRAMS

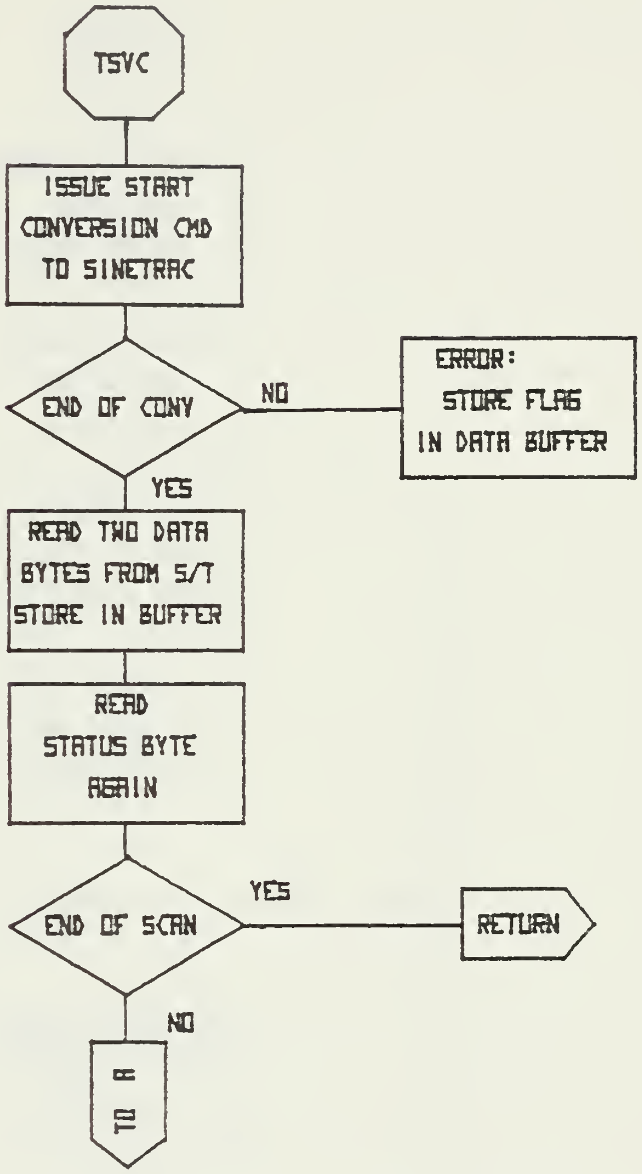
ACQUIRE PROGRAM FLOW DIAGRAM


ACQUIRE
READ 'CONTROL'
EXTRACT CONTROL PARAMETERS
DISPLAY 'CONTROL' FILE ON CRT
CHANGES
YES
NO
DISPLAY 'EDIT CONTROL'
REBOOT TO CP/M
STOP
WRITE 'CONTROL' FILE ON DISK B
SCAN

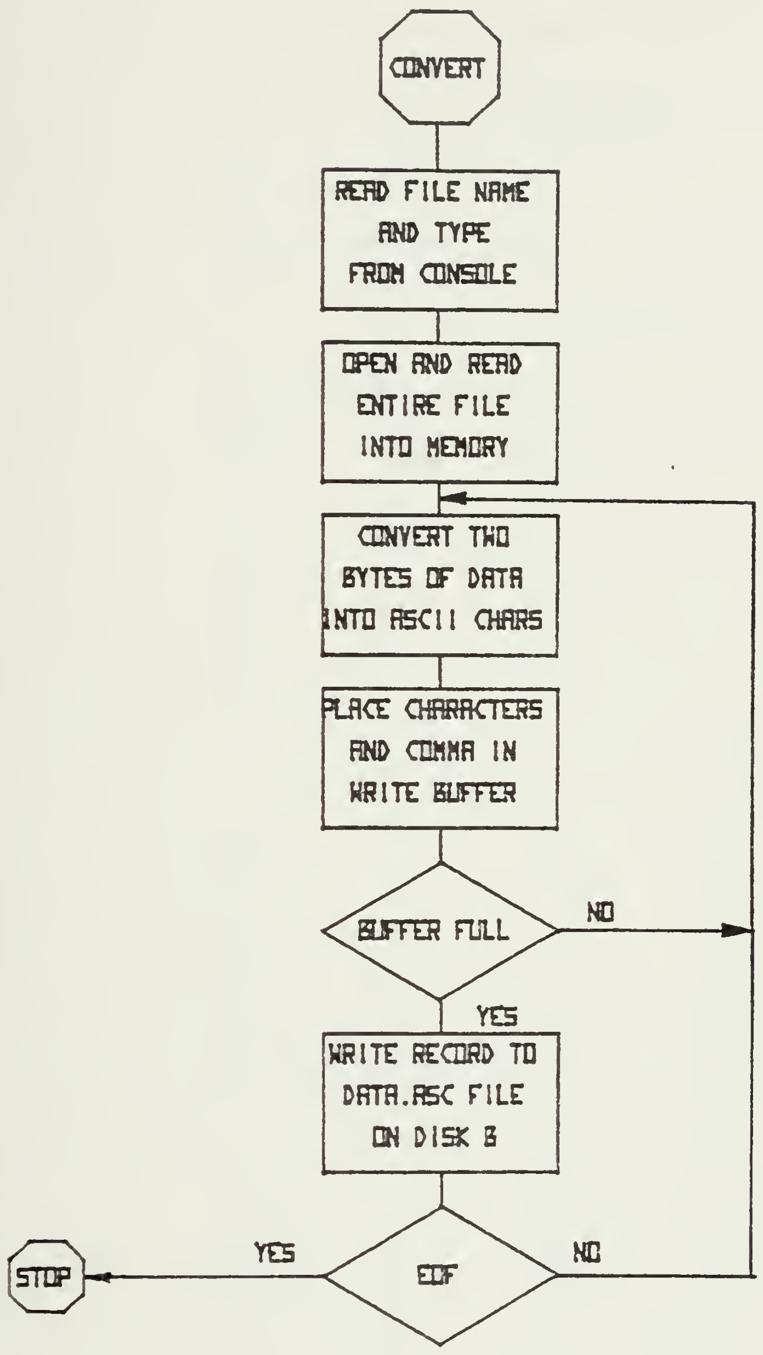
ACQUIRE PROGRAM FLOW DIAGRAM (CONT)


SCAN
SEND INITIAL CHANNEL NO. TO SINETRAC
INITIALIZE AND START TIMER
A
I=1 TO SCANS
WRITE DATA TO DISK FILE 'DATA.NNN'
READ TIME AND STORE IN BUFFER
NNN = NNN + 1
TIMER INTRPT
NO
YES
CALL: TSVC INTRPT SERVICE SUBROUTINE
FINISHED
NO
SCAN
YES
WRITE PROTECT FILE ON DISK B
STOP

ACQUIRE PROGRAM FLOW DIAGRAM (CONT)


TSVC
ISSUE START CONVERSION CMD TO SINETRAC
END OF CONV
NO
ERROR: STORE FLAG IN DATA BUFFER
YES
READ TWO DATA BYTES FROM S/T STORE IN BUFFER
READ STATUS BYTE AGAIN
END OF SCAN
YES
RETURN
NO
TO A

CONVERT PROGRAM FLOW CHART



CONVERT
READ FILE NAME AND TYPE FROM CONSOLE
OPEN AND READ ENTIRE FILE INTO MEMORY
CONVERT TWO BYTES OF DATA INTO ASCII CHARS
PLACE CHARACTERS AND COMMA IN WRITE BUFFER
BUFFER FULL
NO
YES
WRITE RECORD TO DATA.ASC FILE ON DISK B
EOF
YES
NO
STOP

APPENDIX C

PROGRAM LISTINGS

```
                ;*****************************************
                ;       EQUATES FOR DATA ACQUISITION MODULE
                ;
                ;******************************************
                ;
                ;               PORT ASSIGNMENTS
                ;
0000 =          PORT0   EQU     0
0001 =          PORT1   EQU     1
0002 =          PORT2   EQU     2
0003 =          PORT3   EQU     3
                ;
                ;       SINETRACK 800 ADDRESS ASSIGNMENTS
                ;
0010 =          BASE    EQU     10H
0010 =          DSTAT   EQU     BASE
0011 =          DDATA   EQU     BASE+1
0011 =          START   EQU     BASE + 1
0013 =          CONV    EQU     BASE + 3
0012 =          FINAL   EQU     BASE +2
0012 =          RDCUR   EQU     BASE+2
0013 =          RDFNL   EQU     BASE+3
0001 =          EOC     EQU     1
0080 =          EOS     EQU     80H
0000 =          DCMD    EQU     0
                ;
                ;       GENERAL I/O ASSIGNMENTS
                ;
00F4 =          TDATA   EQU     0F4H    ;TTY DATA
00F5 =          TSTAT   EQU     0F5H    ;TTY STATUS
00F5 =          TCMD    EQU     0F5H    ;TTY CONTROL
00F6 =          CDATA   EQU     0F6H    ;CRT DATA
00F7 =          CSTAT   EQU     0F7H    ;CRT STATUS
00F7 =          CCMD    EQU     0F7H    ;CRT CONTROL
00FC =          INTMSK  EQU     0FCH    ;INTERUPT MASK
00FF =          RCLK    EQU     0FFH    ;REAL TIME CLOCK
                ;
                ;       GENERAL EQUATES
                ;
0005 =          ENTRY   EQU     005H    ;BDOS ENTRY POINT
0000 =          BOOT    EQU     00H     ;BOOT POINT
005C =          TFCB    EQU     05CH    ;DEFAULT FCB
0080 =          TBUFF   EQU     080H    ;DEFAULT BUFFER
0001 =          TXRDY   EQU     1
0002 =          RXRDY   EQU     2
000D =          CR      EQU     0DH
000A =          LF      EQU     0AH
                ;******************************************
                ;               BUFFER ALLOCATION &
```

```
                         ;              DATA ORGANIZATION
                         ;
                         ;*****************************************
                         ;
0100                          ORG      100H     ;VARIABLE AREA
0100 C30004                   JMP      BEGIN
0103 5245414420MSG1:          DB       'READ ERROR $'
010F 5752495445MSG2:          DB       'WRITE ERROR $'
011C 4449534B20MSG3:          DB       'DISK FULL $'
0127 4449524543MSG4:          DB       'DIRECTORY FULL $'
0137 494E56414CMSG5:          DB       'INVALID INPUT PARAMETER $'
0150 0D0D0D414EMSG6:          DB       0DH,0DH,0DH,'ANY CHANGES? Y/N $
0165 0D0D0D4544MSG7:          DB       0DH,0DH,0DH,'EDIT CONTROL FILES
017B 0D0D0D4441MSG8:          DB       0DH,0DH,0DH,'DATA DISK PROTECTD
0193 54494D4520MSG10:         DB       'TIME        SV0        SV1 $'
01AE 4441544120MSG11:         DB       'DATA TRUNCATED $'
01BE 474F4F4420MSG12:         DB       'GOOD RUN? Y/N $'
01CD 00434F4E54CNTRL:         DB       0,'CONTROL    ',0,0,0,0,0,0,0
01E0 0050524F54PRTCT:         DB       0,'PROTECT    ',0,0,0,0,0,0,0
01F3 0043414C56CALIB:         DB       0,'CALVALU    ',0,0,0,0,0,0,0
0206 0044415441DATA:          DB       0,'DATA       ',0,0,0,0,0,0,0,0
021A 00         EOFLG:        DB       0
021B 0000       TIME:         DW       0
021D 0000       TIM0:         DW       0
021F 0000       GOTO:         DW       0
0221 0000       POINT:        DW       0        ;BUFFER POINTER
0223 0000       SCNTR:        DW       0        ;SCAN COUNTER
0225 000000000000WORK:        DB       0,0,0,0,0,0      ;WORKING AREA
022B 0000       PAGER:        DW       0        ;PAGE COUNTER
022D 00         RCDS:         DB       0        ;RECORDS STORAGE
022E 00         SV00:         DB       0        ;INITIAL SCANIVALVE 0 B
022F 00         SV01:         DB       0        ;FINAL SCANIVALVE 0 POS
0230 00         SV10:         DB       0        ;INITIAL SCANIVALVE 1 B
0231 00         SV11:         DB       0        ;FINAL SCANIVALVE 1 POS
0232 00         FLAG0:        DB       0        ;FLAG0
0233 00         FLAG1:        DB       0        ;FLAG1
2000                          ORG      2000H    ;START OF DATA AREA
                DBUF:
2000 00         ICHNL:        DB       0
2001 00         FCHNL:        DB       0
2002 00         SV0:          DB       0
2003 00         SV1:          DB       0
2004 0000       SCANS:        DW       0
2006 0000       SCNRT:        DW       0
2008 0000       FREQ:         DW       0
200A 0000       DUMY:         DW       0
200C 00000000                 DW       0,0
0400                          ORG      400H     ;START OF PROGRAM AREA
                BEGIN:
0400 31FF1F                   LXI      SP,1FFFH;INITIALIZE STACK
0403 214207                   LXI      H,TSVC   ;LOAD INTERUPT VECTOR
```

```
0406 3EC3               MVI     A,0C3H
0408 320800             STA     08H
040B 220900             SHLD    09H
040E CD1404             CALL    AUTO
0411 C30000             JMP     BOOT
                ;*****************************************
                ;       AUTO - AUTOMATIC CONTROL SEQUENCE
                ;       USES THE EXISTING CONTROL FILE IF
                ;       IF VALID, SCANS THE SPECIFIED ANALOG
                ;       CHANNELS AND RECORDS DATA ON DISK
                ;****************************************
                AUTO:
0414 CD1705             CALL    PRLOAD  ;VALID CONTROL FILE?
0417 210F02             LXI     H,DATA+9 ;ADDR OF EXTENSION
041A 3E30               MVI     A,'0'   ;ASCII ZERO
041C 77                 MOV     M,A
041D 23                 INX     H
041E 77                 MOV     M,A
041F 23                 INX     H
0420 77                 MOV     M,A
0421 3A2E02             LDA     SV00 ;FETCH INITIAL CHANNEL
0424 320220             STA     SV0     ;INITIALIZE SV0
0427 3A3002             LDA     SV10    ;FETCH INITIAL CHANL
042A 320320             STA     SV1     ;INITIALIZE SV1
042D CD4108             CALL    CRLF    ;CARRIAGE RET LN FEED
0430 119301             LXI     D,MSG10 ;"TIME,SV0,SV1"
0433 CD1108             CALL    PRINT
0436 AF                 XRA     A       ;CLEAR ACCUMULATOR
0437 323202             STA     FLAG0   ;CLEAR FLAG0
043A 323302             STA     FLAG1   ;CLEAR FLAG1
                AUT10:
043D 110040             LXI     D,4000H ;SET HIGH ADDRESS
0440 211020             LXI     H,DBUF+10H
0443 0E00               MVI     C,0
0445 CDE1F9             CALL    0F9E1H
0448 CDE808             CALL    SETVLV
044B 2A1B02             LHLD    TIME    ;FETCH CURRENT TIME
044E CD3408             CALL    PRHL    ;PRINT H,L ON CRT
0451 CD0B05             CALL    TAB
0454 3A0220             LDA     SV0     ;FETCH
0457 CD2708             CALL    PHEX    ;PRINT ASCII PAIR
045A CD0B05             CALL    TAB
045D 3A0320             LDA     SV1
0460 CD2708             CALL    PHEX
0463 CD0B05             CALL    TAB
0466 CDC405             CALL    SCAN
0469 2A2102             LHLD    POINT   ;FETCH BUFFER POINTER
046C 7C                 MOV     A,H
046D D620               SUI     20H
046F 67                 MOV     H,A
0470 29                 DAD     H       ;SHIFT LEFT ONE
```

```
0471 D27E04              JNC     AUT20     ;
0474 26FF                MVI     H,0FFH    ;SET MAX FILE LENGTH
0476 E5                  PUSH    H
0477 11AE01              LXI     D,MSG11   ;"DATA TRUNCATED"
047A CD1108              CALL    PRINT
047D E1                  POP     H
              AUT20:
047E 7C                  MOV     A,H       ;NUMBER RCDS TO WRITE
047F 3C                  INR     A         ;INCREMENT BY ONE
0480 322D02              STA     RCDS      ;STORE IN RCD COUNTER
0483 210020              LXI     H,DBUF    ;POINT TO BEG OF DATA
0486 110602              LXI     D,DATA    ;DATA FCB
0489 CD9507              CALL    WRFILE    ;WRITE THE DATA FILE
048C 3A2F02              LDA     SV01      ;FETCH LST TO BE SCND
048F 47                  MOV     B,A       ;
0490 3A0220              LDA     SV0       ;FETCH CURRENT SV0
0493 B8                  CMP     B         ;SAME?
0494 C2A604              JNZ     AUT22     ;NO - DON'T SET FLAG0
              AUT21:
0497 3EFF                MVI     A,0FFH    ;
0499 323202              STA     FLAG0     ;SET FLAG0
049C 3A2E02              LDA     SV00      ;FETCH FIRST TO SCAN
049F 3D                  DCR     A
04A0 320220              STA     SV0       ;RESET CURRENT CHNL
04A3 C3AB04              JMP     AUT24
              AUT22:
04A6 FE18                CPI     24        ;MAX VALUE EXCEEDED?
04A8 CA9704              JZ      AUT21     ;YES - SET FLAG0
              AUT24:
04AB 3A3102              LDA     SV11      ;LAST SV1 TO SCAN
04AE 47                  MOV     B,A       ;
04AF 3A0320              LDA     SV1       ;FETCH CURRENT SV1
04B2 B8                  CMP     B         ;SAME?
04B3 C2C504              JNZ     AUT32     ;NO - DON'T SET FLAG1
              AUT31:
04B6 3EFF                MVI     A,0FFH    ;
04B8 323302              STA     FLAG1     ;SET FLAG1
04BB 3A3002              LDA     SV10      ;FETCH 1ST TO SCAN
04BE 3D                  DCR     A
04BF 320320              STA     SV1       ;RESET CURRENT CHNL
04C2 C3CA04              JMP     AUT34
              AUT32:
04C5 FE30                CPI     48        ;MAX VALUE EXCEEDED?
04C7 CAB604              JZ      AUT31     ;YES - SET FLAG1
              AUT34:
04CA 3A3202              LDA     FLAG0     ;FETCH FLAG0
04CD 47                  MOV     B,A
04CE 3A3302              LDA     FLAG1     ;FETCH FLAG1
04D1 4F                  MOV     C,A
04D2 A0                  ANA     B         ;BOTH SET?
04D3 C2F504              JNZ     EXIT      ;YES - EXIT AUTO MODE
```

```
                    NEXT:
04D6 3A0220                 LDA     SVO
04D9 3C                     INR     A          ;STEP ONCE
04DA 320220                 STA     SVO
04DD 3A0320                 LDA     SV1
04E0 3C                     INR     A
04E1 320320                 STA     SV1        ;STEP ONCE
04E4 211102                 LXI     H,DATA+11 ;LOAD ADDR OF EXT
                    NEXT1:
04E7 7E                     MOV     A,M ;FETCH ASCII VALUE OF LSB
04E8 3C                     INR     A          ;INCREMENT IT
04E9 77                     MOV     M,A        ;RESTORE IN MEMORY
04EA FE3A                   CPI     ':'        ;EXCEED 9?
04EC DA3D04                 JC      AUT10      ;NO - SCAN AGAIN
04EF 3630                   MVI     M,30H      ;RESTORE IN MEMORY
04F1 2B                     DCX     H          ;GET NEXT MSB
04F2 C3E704                 JMP     NEXT1      ;ADJUST NEXT MSB
                    EXIT:
04F5 11BE01                 LXI     D,MSG12 ;"GOOD RUN Y/N"
04F8 CD1108                 CALL    PRINT
04FB CDFC07                 CALL    CRTIN      ;GET CHAR FROM CONS
04FE FE59                   CPI     'Y'        ;YES RESPONSE?
0500 C0                     RNZ                ;NO - RETURN
0501 11E001                 LXI     D,PRTCT
0504 CD5106                 CALL    SETFCB
0507 CDAE08                 CALL    MAKE        ;WRITE PROTECT FILE
050A C9                     RET
                    TAB:
050B 0608                   MVI     B,8        ;COUNTER FOR 8 BLANKS
                    TAB1:
050D 3E20                   MVI     A,20H      ;ASCII BLANK
050F CD0508                 CALL    CRTOUT     ;SEND TAB CHAR TO CRT
0512 05                     DCR     B
0513 C20D05                 JNZ     TAB1
0516 C9                     RET
                    ;****************************************
                    ;*      PRLOAD - READS IN CONTROL FILE AND
                    ;               EXECUTES IF VALID
                    ;****************************************
                    ;
                    PRLOAD:
0517 CD5008                 CALL    LOGA       ;LOGIN DISK A
051A 11CD01                 LXI     D,CNTRL ;PT TO CNTRL FILE BLK
051D 211020                 LXI     H,DBUF+10H ;PT TO DATA BUFFER
0520 CD7007                 CALL    RDFILE  ;RD CNTRL FILE
0523 111020                 LXI     D,DBUF+10H
0526 D5                     PUSH    D          ;SAVE
0527 CD1108                 CALL    PRINT      ;DISPLAY CONTROL FILE
052A E1                     POP     H          ;RESTORE H
052B CDDB06                 CALL    COLON      ;LOOK FOR FIRST COLON
052E CDDB06                 CALL    COLON      ;LOOK FOR 2ND COLON
```

```
0531 CDDB06          CALL    COLON    ;FIND THIRD COLON
0534 E5              PUSH    H
0535 CDE306          CALL    FLTHX    ;FLOATING TO HEX
0538 220420          SHLD    SCANS    ;STORE HEX IN SCANS
053B E1              POP     H
053C CDDB06          CALL    COLON    ;FIND NEXT COLON
053F E5              PUSH    H
0540 CDE306          CALL    FLTHX    ;FLOATING TO HEX
0543 220620          SHLD    SCNRT    ;STORE IN SCAN RATE
0546 E1              POP     H
0547 CDDB06          CALL    COLON    ;FIND NEXT COLON
054A E5              PUSH    H
054B CDE306          CALL    FLTHX    ;CONVERT
054E 7D              MOV     A,L      ;FETCH RETURNED VALUE
054F 320020          STA     ICHNL    ;PUT IN INITIAL CHNL
0552 E1              POP     H
0553 CDDB06          CALL    COLON
0556 E5              PUSH    H
0557 CDE306          CALL    FLTHX
055A 7D              MOV     A,L      ;FETCH RETURNED BYTE
055B 320120          STA     FCHNL    ;STORE IN FINAL CHNL
055E E1              POP     H
055F CDDB06          CALL    COLON
0562 E5              PUSH    H
0563 CDE306          CALL    FLTHX
0566 7D              MOV     A,L
0567 322E02          STA     SV00     ;1ST SCANIVALVE 0 SET
056A E1              POP     H
056B CDDB06          CALL    COLON
056E E5              PUSH    H
056F CDE306          CALL    FLTHX
0572 7D              MOV     A,L
0573 322F02          STA     SV01     ;LST SCANIVALVE 0 SET
0576 E1              POP     H
0577 CDDB06          CALL    COLON
057A E5              PUSH    H
057B CDE306          CALL    FLTHX
057E 7D              MOV     A,L
057F 323002          STA     SV10     ;1ST SCANIVALVE 1 SET
0582 E1              POP     H
0583 CDDB06          CALL    COLON
0586 E5              PUSH    H
0587 CDE306          CALL    FLTHX
058A 7D              MOV     A,L
058B 323102          STA     SV11     ;LST SCANIVALVE 1 SET
058E E1              POP     H
                ;
                ;*******************************************
                ;       CHECK WITH OPERATOR FOR VALID CONTROL
                ;       FILE
                ;*******************************************
```

```
058F 115001          LXI     D,MSG6  ;"ANY CHANGES?"
0592 CD1108          CALL    PRINT
0595 CDFC07          CALL    CRTIN   ;GET CHAR FROM CONS
0598 FE4E            CPI     'N'     ;"NO" RESPONSE?
059A 116501          LXI     D,MSG7  ;"EDIT CONTROL FILE"
059D C2DA07          JNZ     ERREX   ;EXIT PROGRAM
               ;*****************************************
               ;       WRITE THE CONTROL FILE ON DISK B
               ;*****************************************
05A0 3A6B00          LDA     TFCB+15 ;FETCH RECORD COUNT
05A3 3C              INR     A
05A4 322D02          STA     RCDS    ;STORE IN MEMORY
05A7 CD5808          CALL    LOGB    ;LOGIN DISK B
05AA 11E001          LXI     D,PRTCT ;PT TO PROTECT BLOCK
05AD CD5106          CALL    SETFCB  ;SET FCB
05B0 CDBE08          CALL    SEARCH  ;SEARCH FOR PROTECT
05B3 3C              INR     A       ;DOES IT EXIST?
05B4 117B01          LXI     D,MSG8  ;"DATA DISK PROTECTED"
05B7 C2DA07          JNZ     ERREX   ;YES - EXIT PROGRAM
05BA 11CD01          LXI     D,CNTRL ;PT TO CONTROL BLOCK
05BD 211020          LXI     H,DBUF+10H ;PT TO STORED INFO
05C0 CD9507          CALL    WRFILE  ;WRITE CONTROL TO B
05C3 C9              RET
               ;*****************************************
               ;       SCAN -  COMPLETES N SCANS OF M CHNLS
               ;       ENTRY:  SCANS = NUMBER OF SCANS
               ;               ICHNL =INITIAL CHNL TO SCAN
               ;               FCHNL = FINAL CHANNEL TO SCAN
               ;               TIME  = 2 BYTE TIME IN MS
               ;               EXIT:   REGISTERS UNCHANGED
               ;*****************************************
               ;
               SCAN:
05C4 E5              PUSH    H
05C5 D5              PUSH    D
05C6 C5              PUSH    B
05C7 F5              PUSH    PSW
05C8 3A0020          LDA     ICHNL   ;FETCH INITIAL CHANNEL
05CB D311            OUT     START   ;SET IT
05CD 3A0120          LDA     FCHNL   ;FETCH FINAL CHANNEL
05D0 D312            OUT     FINAL   ;SET IT
05D2 2A0620          LHLD    SCNRT   ;FETCH SCAN RATE
05D5 221D02          SHLD    TIMO    ;STORE IN TIME FACTOR
05D8 21FD05          LXI     H,SCANA ;GET INT SVC JUMP
05DB CD2E07          CALL    TIMER   ;ENABLE INT TIMER
05DE 2A0420          LHLD    SCANS   ;FETCH # OF SCANS
05E1 222302          SHLD    SCNTR   ;PUT IN SCAN COUNTER
05E4 2A1B02          LHLD    TIME    ;FETCH TIME
05E7 21102C          LXI     H,DBUF+10H  ;GET BUFFER LOCAT
05EA 222102          SHLD    POINT   ;STORE IN POINTER
               SCAN8:
```

```
05ED 2A2302           LHLD    SCNTR    ;FETCH SCAN COUNT
05F0 7C               MOV     A,H      ;
05F1 B5               ORA     L        ;FINISHED?
05F2 C2ED05           JNZ     SCAN8    ;NO - KEEP SCANNING
05F5 CD6907           CALL    TIMOFF   ;KILL INTERUPT ROUTINE
05F8 F1               POP     PSW
05F9 C1               POP     B
05FA D1               POP     D
05FB E1               POP     H        ;RETORED
05FC C9               RET
               SCANA:
05FD E5               PUSH    H
05FE D5               PUSH    D
05FF C5               PUSH    B
0600 F5               PUSH    PSW
0601 2A0620           LHLD    SCNRT    ;GET SCAN RATE
0604 221D02           SHLD    TIMO     ;RESET TIMOUT FACTOR
0607 2A2102           LHLD    POINT    ;GET BUFFER POINTER
060A 3E00             MVI     A,DCMD   ;INITIALIZATION CMD
060C D310             OUT     DSTAT    ;SET FLIP FLOPS
060E 3A1B02           LDA     TIME     ;GET TIME
0611 77               MOV     M,A      ;STORE IN BUFFER
0612 23               INX     H        ;MOVE POINTER
0613 3A1C02           LDA     TIME+1   ;GET 2ND BYTE OF TIME
0616 77               MOV     M,A      ;STORE IN DATA CELL
0617 23               INX     H        ;MOVE POINTER
               SCANO:
0618 D313             OUT     CONV     ;START CONVERSION
061A 3E02             MVI     A,2      ;SET DELAY COUNTER
061C 00               NOP              ;EXTRA DELAY
               SCAN1:
061D 3D               DCR     A        ;QUIT LOOP?
061E C21D06           JNZ     SCAN1    ;NO - KEEP COUNTING
0621 DB10             IN      DSTAT    ;FETCH STATUS
0623 E601             ANI     EOC
0625 C23106           JNZ     SCAN3    ;YES - GO READ DATA
0628 3600             MVI     M,00H    ;INSERT ERROR FLAG
062A 23               INX     H        ;MOVE POINTER
062B 3600             MVI     M,00H    ;INSERT ERROR FLAG
062D 23               INX     H        ;MOVE POINTER
062E C33906           JMP     SCAN4    ;READ NEXT CHANNEL
               SCAN3:
0631 DB11             IN      DDATA    ;GET LSB OF DATA
0633 77               MOV     M,A      ;STORE
0634 23               INX     H        ;MOVE POINTER
0635 DB11             IN      DDATA    ;GET MSB OF DATA
0637 77               MOV     M,A      ;STORE
0638 23               INX     H        ;MOVE POINTER
               SCAN4:
0639 DB10             IN      DSTAT    ;FETCH STATUS
063B E680             ANI     EOS      ;END OF SCAN?
```

```
063D CA1806                 JZ      SCANO      ;NO - CONV NEXT CHNL
0640 222102                 SHLD    POINT      ;STORE POINTER
0643 2A2302                 LHLD    SCNTR      ;FETCH SCAN COUNT
0646 2B                     DCX     H          ;COUNT DOWN ONE
0647 222302                 SHLD    SCNTR      ;RESTORE UPDATED COUNT
064A F1                     POP     PSW
064B C1                     POP     B
064C D1                     POP     D
064D E1                     POP     H
064E C35C07                 JMP     TSVCO               ;RETURN
                ;*****************************************
                ;       SETFCB - MOVES AN INITIAL FCB INTO
                ;                TFCB AREA
                ;               ENTRY:  D,E = FILNAME BLOCK
                ;*****************************************
                ;
                SETFCB:
0651 E5                     PUSH    H          ;SAVE
0652 215C00                 LXI     H,05CH     ;DEFAULT FCB
0655 C5                     PUSH    B          ;SAVE
0656 0613                   MVI     B,19       ;SET COUNTER
                SETF1:
0658 1A                     LDAX    D          ;FETCH BYTE TO MOVE
0659 77                     MOV     M,A        ;STORE IN TFCB AREA
065A 23                     INX     H          ;INCREMENT H
065B 13                     INX     D          ;INCREMENT D
065C 05                     DCR     B          ;FINISHED?
065D C25806                 JNZ     SETF1      ;NO -GET ANOTHER BYTE
0660 AF                     XRA     A          ;CLEAR ACCUM
0661 327C00                 STA     TFCB+32
0664 C1                     POP     B
0665 E1                     POP     H
0666 C9                     RET
                ;*****************************************
                ;       DECHX - CONVERTS 6 BCD BYTES TO 2 HEX
                ;*              ENTRY: SIX BCD BYTES STARTING
                ;                       AT 'WORK'
                ;*              EXIT: TWO HEX AT 'WORK+4'
                ;*****************************************
                ;
                DECHX:
0667 212502                 LXI     H,WORK     ;POINT TO WORK AREA
066A 54                     MOV     D,H        ;DUPLICATE IN D
066B 5D                     MOV     E,L        ;DUPLICATE IN E
066C CD8506                 CALL    HEXBIN     ;CONVERT 1ST PR TO HEX
066F 12                     STAX    D          ;STORE IN WORK
0670 13                     INX     D          ;MOVE STORAGE POINTER
0671 CD8506                 CALL    HEXBIN     ;CONVERT SECOND PAIR
0674 12                     STAX    D          ;STORE IN WORK+1
0675 13                     INX     D          ;MOVE POINTER
0676 CD8506                 CALL    HEXBIN     ;CONVERT THIRD PAIR
```

```
0679 12               STAX    D
067A 13               INX     D
067B AF               XRA     A          ;CLEAR ACCUMULATOR
067C 12               STAX    D          ;LOAD ZERO IN WORK+3
067D 13               INX     D          ;MOVE POINTER
067E 212502           LXI     H,WORK
0681 CD8E06           CALL    BCD2HX
0684 C9               RET                ;RETURN
                ;*******************************************
                ;SUBROUTINES - BCD2HX AND HEXBIN
                ;*****************************************
                ;
                ;
                HEXBIN:
0685 7E               MOV     A,M        ;FETCH 1ST BYTE
0686 17               RAL
0687 17               RAL
0688 17               RAL
0689 17               RAL                ;SHIFTED TO HIGH NIB
068A 23               INX     H          ;MOVE POINTER
068B B6               ORA     M          ;BRING IN LOW NIBBLE
068C 23               INX     H          ;MOVE POINTER
068D C9               RET                ;RETURN
                BCD2HX:
068E CDC906           CALL    BCDBN
0691 23               INX     H
0692 CDC906           CALL    BCDBN
0695 23               INX     H
0696 CDC906           CALL    BCDBN
0699 CD9D06           CALL    MULT
069C C9               RET
                MULT:
069D 3A2502           LDA     WORK
06A0 5F               MOV     E,A
06A1 1600             MVI     D,0
06A3 210000           LXI     H,0
06A6 CDC106           CALL    MUL10
06A9 EB               XCHG
06AA 210000           LXI     H,0
06AD CDC106           CALL    MUL10
06B0 3A2602           LDA     WORK+1
06B3 1600             MVI     D,0
06B5 5F               MOV     E,A
06B6 CDC106           CALL    MUL10
06B9 3A2702           LDA     WORK+2
06BC 1600             MVI     D,0
06BE 5F               MOV     E,A
06BF 19               DAD     D
06C0 C9               RET
                MUL10:
06C1 0664             MVI     B,100
```

```
                   MUL20:
06C3 19                      DAD     D
06C4 05                      DCR     B
06C5 C2C306                  JNZ     MUL20
06C8 C9                      RET
                   BCDBN:
06C9 7E                      MOV     A,M
06CA 4F                      MOV     C,A
06CB E60F                    ANI     0FH
06CD 5F                      MOV     E,A
06CE 79                      MOV     A,C
06CF E6F0                    ANI     0F0H
06D1 0F                      RRC
06D2 0F                      RRC
06D3 4F                      MOV     C,A
06D4 0F                      RRC
06D5 0F                      RRC
06D6 81                      ADD     C
06D7 07                      RLC
06D8 83                      ADD     E
06D9 77                      MOV     M,A
06DA C9                      RET
                   ;*****************************************
                   ;         COLON - FINDS THE NEXT COLON ":"
                   ;                 IN MEMORY STARTING AT H,L
                   ;                 EXIT:   H,L POINTS TO MEMORY
                   ;                         POSITION AFTER ":"
                   ;*****************************************
                   ;
                   COLON:
06DB 3E3A                    MVI     A,':'
                   COL10:
06DD BE                      CMP     M
06DE 23                      INX     H
06DF C2DD06                  JNZ     COL10
06E2 C9                      RET
                   ;*****************************************
                   ;         FLTHX - SCANS A BLOCK OF MEMORY FOR
                   ;                 BCD ASCII CHARACTERS AND
                   ;                 CONVERTS THEM TO A PAIR OF
                   ;                 HEX BYTES
                   ;******************************************
                   FLTHX:
06E3 0606                    MVI     B,6      ;SET LOOP COUNTER
06E5 E5                      PUSH    H        ;SAVE
06E6 C5                      PUSH    B        ;SAVE
06E7 212502                  LXI     H,WORK   ;INITIALIZE
06EA AF                      XRA     A        ;   WORK
                   FLT04:
06EB 77                      MOV     M,A      ;      AREA
06EC 23                      INX     H        ;         TO
```

```
06ED 05              DCR     B         ;                   ZEROS
06EE C2EB06          JNZ     FLT04     ;
06F1 C1              POP     B         ;RESTORE
06F2 E1              POP     H         ;RESTORE
             FLT05:
06F3 7E              MOV     A,M       ;FETCH FIRST CHAR
06F4 FE20            CPI     ' '       ;IS IT A BLANK?
06F6 CA0F07          JZ      FLT10     ;YES - IGNORE IT
06F9 FE0D            CPI     CR        ;IS IT A CARRIAGE RTN
06FB CA1307          JZ      FLT20     ;YES QUIT SCANNING
06FE E6F0            ANI     0F0H      ;MASK OFF LOW NIBBLE
0700 FE30            CPI     30H       ;IS IT IN HEX RANGE?
0702 C22807          JNZ     FLT30     ;NO - IT IS AN ERROR
0705 7E              MOV     A,M       ;FETCH THE WORD AGAIN
0706 FE3A            CPI     3AH       ;IS IT > 9
0708 F22807          JP      FLT30     ;YES - IT IS AN ERROR
070B 05              DCR     B         ;COUNT AS A VALID HEX
070C FA2807          JM      FLT30     ;ERROR IF > 6 NUMBERS
             FLT10:
070F 23              INX     H         ;STEP MEMORY POINTER
0710 C3F306          JMP     FLT05     ;SCAN AGAIN
             FLT20:
0713 3E06            MVI     A,6       ;
0715 90              SUB     B         ;COMPUTE # DIGITS
0716 47              MOV     B,A       ;STORE IN B
0717 2B              DCX     H         ;BACK SPACE POINTER
0718 112A02          LXI     D,WORK+5;POINT TO WORK AREA
             FLT25:
071B 7E              MOV     A,M       ;FETCH NEXT LSB
071C E60F            ANI     0FH       ;CONVERT TO BCD
071E 12              STAX    D         ;STORE IN WORK AREA
071F 1B              DCX     D         ;MOVE  POINTER
0720 2B              DCX     H         ;MOVE SOURCE POINTER
0721 05              DCR     B         ;COUNT DOWN
0722 C21B07          JNZ     FLT25     ;DO AGAIN
0725 C36706          JMP     DECHX     ;CONVERT TO HEXBYTE
             FLT30:
0728 113701          LXI     D,MSG5    ;"INVALID INPUT FIELD"
072B C3DA07          JMP     ERREX
             ;*****************************************
             ;       TIMER - INTERUPTS TO SPECIFIED
             ;               ROUTINE AFTER NN MILLISECONDS
             ;       ENTRY:  H,L = STARTING ADDR
             ;               OF INTERUPT SERVICE ROUTINE
             ;               D,E = TIMEOUT IN MS
             ;       EXIT:   REGISTERS REMAIN UNCHANGED
             ;               SERVICE ROUTINE IS EXECUTED
             ;               INTERUPT ROUTINE SHOULD LOOK
             ;               LIKE NORMAL SUBROUTINE
             ;*****************************************
             ;
```

```
                      TIMER:
072E F3                        DI
072F 221F02                    SHLD     GOTO     ;STORE JUMP ADDRESS
0732 DBFC                      IN       INTMSK   ;FETCH  INT MASK
0734 E6FD                      ANI      OFDH     ;ENABLE TIMER INT
0736 D3FC                      OUT      INTMSK   ;SET INTERUPT MASK
0738 3E12                      MVI      A,12H
073A D3FD                      OUT      OFDH     ;INIT INT CONTROLLER
073C 3E02                      MVI      A,02H    ;
073E D3FF                      OUT      OFFH     ;START TIMER
0740 FB                        EI
0741 C9                        RET
                      ;
                      ;                 TIMER INTERUPT SERVICE
                      ;
                      TSVC:
0742 F3                        DI                ;DISABLE INTERUPTS
0743 F5                        PUSH     PSW      ;SAVE A
0744 E5                        PUSH     H
0745 3E02                      MVI      A,02H
0747 D3FF                      OUT      OFFH     ;RESET TIMER
0749 2A1B02                    LHLD     TIME     ;GET TIME
074C 23                        INX      H        ;UPDATE
074D 221B02                    SHLD     TIME     ;RESTORE
0750 2A1D02                    LHLD     TIMO     ;GET TIMOUT COUNT
0753 2B                        DCX      H        ;COUNT DOWN
0754 221D02                    SHLD     TIMO     ;RESTORE IT
0757 7C                        MOV      A,H      ;GET MSB OF COUNT
0758 B5                        ORA      L        ;OR WITH LSB OF COUNT
0759 CA6507                    JZ       TSVC1    ;TO INT ROUTINE IF 0
                      TSVCO:
075C E1                        POP      H        ;RESTORE
075D F3                        DI
075E 3E20                      MVI      A,20H    ;RESTORE INT LEVEL
0760 D3FD                      OUT      OFDH
0762 F1                        POP      PSW      ;RESTORE
0763 FB                        EI                ;ENABLE INTERUPTS
0764 C9                        RET               ;RETURN
                      TSVC1:
0765 2A1F02                    LHLD     GOTO     ;FETCH JUMP ADDRESS
0768 E9                        PCHL              ;EXECUTE JUMP
                      ;****************************************
                      ;        TIMOFF - TURNS OFF INTERUPT SERVICE
                      ;*****************************************
                      ;
                      TIMOFF:
0769 F5                        PUSH     PSW
076A 3E01                      MVI      A,01H
076C D3FF                      OUT      OFFH
076E F1                        POP      PSW
076F C9                        RET
```

```
                ;*******************************************
                ;*       RDFILE - READ AN ENTIRE FILE INTO
                ;*                MEMORY
                ;*       ENTRY: STARTING ADDR OF MEMORY BLOCK
                ;*              IN H,L
                ;*               ADDR OF FILENAME BLOCK IN D,E
                ;********************************************
                ;
                RDFILE:
0770 222B02             SHLD    PAGER    ;STORE  POINTER
0773 CD5106             CALL    SETFCB
0776 CD6008             CALL    OPEN     ;OPEN FILE
0779 AF                 XRA     A        ;CLEAR ACCUM
077A 321A02             STA     EOFLG    ;CLEAR EOF FLAG
                RDF10:
077D 2A2B02             LHLD    PAGER    ;FETCH POINTER
0780 EB                 XCHG             ;PUT POINTER IN D,E
0781 CDC608             CALL    SETDMA
0784 CD7008             CALL    READ     ;READ A RECORD
0787 CDC907             CALL    HAFPG    ;MOVE PAGE INDEX
078A 3A1A02             LDA     EOFLG    ;FETCH EOF FLAG
078D B7                 ORA     A        ;EOF FOUND?
078E CA7D07             JZ      RDF10    ;NO - READ NEW PAGE
0791 CD6808             CALL    CLOSE    ;CLOSE FILE
0794 C9                 RET              ;RETURN
                ;*******************************************
                ;        WRFILE - WRITE A BLOCK OF MEMORY
                ;        ENTRY:  NUMBER OF RECORDS+1 TO WRITE
                ;                STARTING ADDRESS IN H,L
                ;*******************************************
                ;
                WRFILE:
0795 222B02             SHLD    PAGER    ;SET UP PAGER
0798 CD5106             CALL    SETFCB   ;SET FCB
079B 118000             LXI     D,80H
079E CDC608             CALL    SETDMA
07A1 CDBE08             CALL    SEARCH   ;SEARCH FOR EXISTING
07A4 3C                 INR     A        ;WAS THERE A MATCH?
07A5 C2AB07             JNZ     WRF05    ;YES - SKIP MAKE
07A8 CDAE08             CALL    MAKE     ;MAKE DIRECTORY ENTRY
                WRF05:
07AB CD6008             CALL    OPEN     ;OPEN FILE
                WRF10:
07AE 2A2B02             LHLD    PAGER    ;FETCH CURRENT POINTER
07B1 EB                 XCHG             ;PUT POINTER IN D,E
07B2 CDC608             CALL    SETDMA
                WRF15:
07B5 CD8A08             CALL    WRITE    ;WRITE A RECORD
07B8 CDC907             CALL    HAFPG    ;MOVE PAGE INDEX
07BB 3A2D02             LDA     RCDS     ; RECORDS TO WRITE
07BE 216B00             LXI     H,TFCB+15
```

```
07C1 BE                 CMP     M
07C2 C2B507             JNZ     WRF15    ;NO-WRITE NEW RECORD
07C5 CD6808             CALL    CLOSE    ;CLOSE THE FILE
07C8 C9                 RET              ;     RETURN
              ;*****************************************
              ;       SUBROUTINE HAFPGE - ADJUSTS DMA ADDRESS
              ;               HALF PAGE OF MEMORY
              ;*****************************************
              ;
              HAFPG:
07C9 E5                 PUSH    H        ;SAVE
07CA 2A2B02             LHLD    PAGER
07CD 118000             LXI     D,0128   ;
07D0 19                 DAD     D        ;ADD 128 TO PAGER
07D1 222B02             SHLD    PAGER    ;RESTORE UPDATD PAGER
07D4 EB                 XCHG             ;SWITCH H,L WITH D,E
07D5 CDC608             CALL    SETDMA   ;SET DMA
07D8 E1                 POP     H
07D9 C9                 RET
              ;*****************************************
              ;       ERREX - FATAL ERRORS EXIT VIA THIS
              ;       ENTRY: D,E CONTAIN MESSAGE ADDRESS
              ;       EXIT:   BOOT TO DOS
              ;*****************************************
              ;
              ERREX:
07DA CD1108             CALL    PRINT    ;PRINT THE MESSAGE
07DD 115C00             LXI     D,TFCB   ;TEMPORARY FCB
07E0 CD6808             CALL    CLOSE    ;CLOSE THE FILE
07E3 C30000             JMP     BOOT     ;BOOT TO DOS
              ;*****************************************
              ;       DRIVERS - I/O SUBROUTINES CONTAINING
              ;                 TTY, CRT, DISK, I/O PORTS
              ;*******************************************
              ;
              ;                 TTY DRIVERS
              ;
              TTYIN:
07E6 DBF5               IN      TSTAT    ;FETCH STATUS
07E8 E602               ANI     RXRDY    ;IS RECEIVER READY
07EA CAE607             JZ      TTYIN    ;NO KEEP LOOKING
07ED DBF4               IN      TDATA    ;FETCH DATA BYTE
07EF C9                 RET              ;RETURN W/ BYTE IN A
              TTYOUT:
07F0 F5                 PUSH    PSW      ;SAVE DATA BYTE
07F1 DBF5               IN      TSTAT    ;FETCH STATUS
07F3 E601               ANI     TXRDY    ;TRANSMITTER RDY?
07F5 CAF007             JZ      TTYOUT   ;NO - WAIT UNTIL RDY
07F8 F1                 POP     PSW      ;BRING BACK DATA BYTE
07F9 D3F4               OUT     TDATA    ;OUTPUT TO TTY
07FB C9                 RET              ;RETURN
```

```
                    CRTIN:
07FC DBF7                   IN      CSTAT     ;FETCH CRT STATUS
07FE E602                   ANI     RXRDY     ;RECEIVER READY ?
0800 CAFC07                 JZ      CRTIN     ;NO - WAIT UNTIL RDY
0803 DBF6                   IN      CDATA     ;FETCH INPUT BYTE
                    CRTOUT:
0805 F5                     PUSH    PSW       ;SAVE DATA BYTE
                    CRT1:
0806 DBF7                   IN      CSTAT     ;FETCH CRT STATUS
0808 E601                   ANI     TXRDY     ;TXMITTER READY ?
080A CA0608                 JZ      CRT1      ;NO - WAIT UNTIL RDY
080D F1                     POP     PSW       ;BRING BACK DATA
080E D3F6                   OUT     CDATA     ;OUTPUT DATA
0810 C9                     RET               ;RETURN
                    PRINT:
0811 0E09                   MVI     C,9       ;SET UP FOR BDOS CALL
0813 C30500                 JMP     ENTRY     ;JUMP TO BDOS
                    PNIB:
0816 E60F                   ANI     0FH       ;MASK LOW 4 BITS
0818 FE0A                   CPI     10
081A D22208                 JNC     P10
081D C630                   ADI     '0'
081F C30508                 JMP     CRTOUT
                    P10:
0822 C637                   ADI     'A' - 10
0824 C30508                 JMP     CRTOUT
                    PHEX:
0827 F5                     PUSH    PSW
0828 0F                     RRC
0829 0F                     RRC
082A 0F                     RRC
082B 0F                     RRC
082C CD1608                 CALL    PNIB
082F F1                     POP     PSW
0830 CD1608                 CALL    PNIB
0833 C9                     RET
                    PRHL:
0834 E5                     PUSH H
0835 7C                     MOV     A,H
0836 CD2708                 CALL    PHEX
0839 E1                     POP     H
083A E5                     PUSH    H
083B 7D                     MOV     A,L
083C CD2708                 CALL    PHEX
083F E1                     POP     H
0840 C9                     RET
                    CRLF:
0841 3E0D                   MVI     A,0DH     ;CARRIAGE RETURN
0843 CD0508                 CALL    CRTOUT
0846 3E0A                   MVI     A,0AH     ;LINE FEED
0848 C30508                 JMP     CRTOUT
```

```
                  INTIAL:
084B 0E0D                   MVI     C,13
084D C30500                 JMP     ENTRY
                  LOGA:
0850 110000                 LXI     D,00H
0853 0E0E                   MVI     C,14
0855 C30500                 JMP     ENTRY
                  LOGB:
0858 110100                 LXI     D,01H
085B 0E0E                   MVI     C,14
085D C30500                 JMP     ENTRY
                  OPEN:
0860 115C00                 LXI     D,05CH
0863 0E0F                   MVI     C,15
0865 C30500                 JMP     ENTRY
                  CLOSE:
0868 115C00                 LXI     D,05CH
086B 0E10                   MVI     C,16
086D C30500                 JMP     ENTRY
                  READ:
0870 115C00                 LXI     D,05CH
0873 0E14                   MVI     C,20
0875 CD0500                 CALL    ENTRY
0878 B7                     ORA     A
0879 C8                     RZ              ;RETURN IF NO ERRORS
087A 3D                     DCR     A       ;IS IT AN EOF?
087B C28408                 JNZ     RD010   ;NO -UNWRITTEN DATA
087E 3E0F                   MVI     A,0FH   ;SET EOF FLAG
0880 321A02                 STA     EOFLG   ;
0883 C9                     RET
                  RD010:
0884 110301                 LXI     D,MSG1  ;'READ ERROR'
0887 C3DA07                 JMP     ERREX
                  WRITE:
088A 115C00                 LXI     D,05CH
088D 0E15                   MVI     C,21
088F CD0500                 CALL    ENTRY
0892 B7                     ORA     A
0893 C8                     RZ              ;RETURN IF NO ERRORS
0894 3D                     DCR     A       ;
0895 C29E08                 JNZ     WR010
0898 110F01                 LXI     D,MSG2  ;'WRITE ERROR'
089B C3DA07                 JMP     ERREX
                  WR010:
089E 3D                     DCR     A
089F C2A808                 JNZ     WR020
08A2 111C01                 LXI     D,MSG3  ;'DISK FULL'
08A5 C3DA07                 JMP     ERREX
                  WR020:
08A8 112701                 LXI     D,MSG4  ;'DIRECTORY FULL'
08AB C3DA07                 JMP     ERREX
```

```
                MAKE:
08AE 115C00             LXI     D,05CH
08B1 0E16               MVI     C,22
08B3 CD0500             CALL    ENTRY
08B6 3C                 INR     A
08B7 C0                 RNZ
08B8 112701             LXI     D,MSG4   ;'DIRECTORY FULL'
08BB C3DA07             JMP     ERREX
                SEARCH:
08BE 115C00             LXI     D,05CH
08C1 0E11               MVI     C,17
08C3 C30500             JMP     ENTRY
                SETDMA:
08C6 0E1A               MVI     C,26
08C8 C30500             JMP     ENTRY
                ;*****************************************
                ;       SETVLV - ALLOWS USER TO SET UP PROPER
                ;       SCANIVALVE POSITION BEFORE CONTINUING
                ;*****************************************
                ;
08CB 494E5055554MESS:   DB      'INPUT FREQUENCY TYPE RETURN $'
                SETVLV:
08E8 CD4108             CALL    CRLF
08EB 11CB08             LXI     D,MESS
08EE CD1108             CALL    PRINT
08F1 CDFC07             CALL    CRTIN
08F4 E60F               ANI     OFH
08F6 322702             STA     WORK+2
08F9 CDFC07             CALL    CRTIN
08FC E60F               ANI     OFH
08FE 322802             STA     WORK+3
0901 CDFC07             CALL    CRTIN
0904 E60F               ANI     OFH
0906 322902             STA     WORK+4
0909 CDFC07             CALL    CRTIN
090C E60F               ANI     OFH
090E 322A02             STA     WORK+5
0911 CDFC07             CALL    CRTIN
0914 E67F               ANI     7FH
0916 FE0D               CPI     CR
0918 C2E808             JNZ     SETVLV
091B AF                 XRA     A
091C 322502             STA     WORK
091F 322602             STA     WORK+1
0922 CD6706             CALL    DECHX
0925 7D                 MOV     A,L
0926 320820             STA     SCNRT + 2
0929 7C                 MOV     A,H
092A 320920             STA     SCNRT+3
092D C9                 RET
092E                    END 100H
```

```
                    ;**
                    ;               EQUATES FOR CONVERT MODULE
                    ;
                    ;**
                    ;
                    ;               GENERAL I/O ASSIGNMENTS
                    ;
00F4 =              TDATA   EQU     0F4H    ;TTY DATA
00F5 =              TSTAT   EQU     0F5H    ;TTY STATUS
00F5 =              TCMD    EQU     0F5H    ;TTY CONTROL
00F6 =              CDATA   EQU     0F6H    ;CRT DATA
00F7 =              CSTAT   EQU     0F7H    ;CRT STATUS
00F7 =              CCMD    EQU     0F7H    ;CRT CONTROL
                    ;
                    ;               GENERAL EQUATES
                    ;
0005 =              ENTRY   EQU     005H    ;BDOS ENTRY POINT
0000 =              BOOT    EQU     00H     ;BOOT POINT
005C =              TFCB    EQU     05CH    ;DEFAULT FCB
0080 =              TBUFF   EQU     080H    ;DEFAULT BUFFER LOCATIO
0001 =              TXRDY   EQU     1
0002 =              RXRDY   EQU     2
000D =              CR      EQU     0DH
000A =              LF      EQU     0AH
                    ;**
                    ;               BUFFER ALLOCATION &
                    ;               DATA ORGANIZATION
                    ;
                    ;**
                    ;
                    ;
0100                        ORG     100H    ;VARIABLE AREA
0100 C30004                 JMP     BEGIN
0103 5245414420MSG1:        DB      'READ ERROR $'
010F 5752495445MSG2:        DB      'WRITE ERROR $'
011C 4449534B20MSG3:        DB      'DISK FULL $'
0127 4449524543MSG4:        DB      'DIRECTORY FULL $'
0137 4441544120MSG11:       DB      'DATA TRUNCATED $'
0147 0044415441DATA:        DB      0,'DATA       ',0,0,0,0,0,0,0,0
015B 00             EOFLG:  DB      0
015C 0000           TIME:   DW      0
015E 0000           TIMO:   DW      0
0160 0000           GOTO:   DW      0
0162 0000           POINT:  DW      0       ;BUFFER POINTER
0164 0000           SCNTR:  DW      0       ;SCAN COUNTER
0166 0000000000WORK:        DB      0,0,0,0,0,0     ;WORKING AREA B
016C 0000           PAGER:  DW      0       ;PAGE COUNTER
016E 00             RCDS:   DB      0       ;RECORDS TO BE WRITTENS
016F 0000           LASTM:  DW      00      ;LAST WRITTEN LOCATION
```

```
2000                   ORG     2000H    ;START OF DATA AREA
              DBUF:
0400                   ORG     400H     ;START OF PROGRAM AREA
              BEGIN:
0400 31FF1F            LXI     SP,1FFFH          ;INITIALIZE STG
0403 CD0904            CALL    TRANS
0406 C30000            JMP     BOOT
              ***************************************************
              ;        TRANS - READS IN DATA FILE FROM DISK B
              ;                CONVERTS BINARY DATA TO ASCII B
              ;                REQUIRED BY BASIC ROUTINE
              ;                ENTRY: THIS PROGRAM IS CALLED B
              ;                         SUBMIT FILE
              ;                EXIT:    CONTROL IS RETURNED TOS
              ;                         FILE
              ;**************************************************
              ;
              ;        SET UP FILE CONTROL BLOCK - READS IN SE
              ;        ETER ISSUED BY SUBMIT FILE
              ;**************************************************
              ;
              TRANS:
0409 118200            LXI     D,082H   ;ADDRESS OF PARAMETER L
040C 0604              MVI     B,4      ;CHARACTER COUNTER
040E 215C00            LXI     H,05CH   ;ADDRESS OF TFCB
0411 3600              MVI     M,0
0413 23                INX     H
              TRAN1:
0414 1A                LDAX    D        ;FETCH CHARACTER
0415 77                MOV     M,A      ;STORE IN FCB
0416 13                INX     D        ;STEP POINTER
0417 23                INX     H        ;STEP DESTINATION POINT
0418 05                DCR     B        ;FINISHED?
0419 C21404            JNZ     TRAN1    ;NO KEEP TRANSFERRING
041C 13                INX     D
041D 3E20              MVI     A,20H
041F 77                MOV     M,A
0420 23                INX     H
0421 77                MOV     M,A
0422 23                INX     H
0423 77                MOV     M,A
0424 23                INX     H
0425 77                MOV     M,A
0426 23                INX     H
0427 1A                LDAX    D
0428 77                MOV     M,A
0429 23                INX     H
042A 13                INX     D
042B 1A                LDAX    D
042C 77                MOV     M,A
042D 23                INX     H
```

```
042E 13                 INX     D
042F 1A                 LDAX    D
0430 77                 MOV     M,A
0431 0618               MVI     B,24
0433 AF                 XRA     A          ;CLEAR A
                TRAN2:
0434 23                 INX     H
0435 77                 MOV     M,A
0436 05                 DCR     B
0437 C23404             JNZ     TRAN2
                ;**********************************************
                ;       READ IN DATA FILE
                ;**********************************************
                ;
043A CDC405             CALL    LOGB       ;LOGIN DISK B
043D 210020             LXI     H,DBUF     ;BUFFER AREA
0440 226C01             SHLD    PAGER      ;SET PAGER
0443 CDCC05             CALL    OPEN       ;OPEN FOR READ
0446 AF                 XRA     A          ;CLEAR A
0447 325B01             STA     EOFLG      ;RESET END OF FILE FLAG
044A 110020             LXI     D,DBUF
044D CD3A06             CALL    SETDMA
0450 CD6206             CALL    RDF10      ;READ FILE INTO MEMORY
0453 2A6C01             LHLD    PAGER
0456 117EFF             LXI     D,0FF7EH
0459 19                 DAD     D
045A 226F01             SHLD    LASTM      ;SAVE LAST MEMORY LOCAT
                ;**********************************************
                ;       SET UP TRANSITION BUFFER IN DEFAULT LOG
                ;**********************************************
045D 118000             LXI     D,080H     ;ADDRESS OF TBUFF
0460 CD3A06             CALL    SETDMA     ;SET DMA ADDRESS
0463 215001             LXI     H,DATA+9           ;ADDRESS OF EXI
0466 3641               MVI     M,'A'
0468 23                 INX     H
0469 3653               MVI     M,'S'
046B 23                 INX     H
046C 3643               MVI     M,'C'
046E 114701             LXI     D,DATA
0471 CD3F06             CALL    SETFCB     ;SET FILE CONTROL BLOCK
0474 CD1A06             CALL    DELET
0477 CD2206             CALL    MAKE
047A CDCC05             CALL    OPEN
047D 218000             LXI     H,080H     ;ADDRESS OF TBUFF
0480 226201             SHLD    POINT      ;SET BUFFER POINTER TOT
0483 210020             LXI     H,DBUF     ;ADDRESS OF DBUF
0486 226C01             SHLD    PAGER
0489 CDBA04             CALL    GTONE
048C CDBA04             CALL    GTONE
048F CDBA04             CALL    GTONE
0492 CDBA04             CALL    GTONE
```

```
0495 2A6F01             LHLD    LASTM
0498 EB                 XCHG
                CONVT:
0499 CDCE04             CALL    GTTWO
049C 2A6F01             LHLD    LASTM
049F EB                 XCHG
04A0 2A6C01             LHLD    PAGER
04A3 7B                 MOV     A,E
04A4 95                 SUB     L
04A5 7A                 MOV     A,D
04A6 9C                 SBB     H
04A7 D29904             JNC     CONVT
04AA 2A6201             LHLD    POINT
04AD 3E30               MVI     A,'0'
                CON10:
04AF CDF504             CALL    STUFF
04B2 2C                 INR     L
04B3 C2AF04             JNZ     CON10
04B6 CDD405             CALL    CLOSE
04B9 C9                 RET
                ;***********************************************
                ;       GTONE - TAKES ONE BYTE FROM DATA BUFFER
                ;               CONVERTS TO ASCII IN TBUF
                ;               TBUF IS EMPTIED WHEN FULL
                ;***********************************************
                GTONE:
04BA 2A6C01             LHLD    PAGER
04BD 7E                 MOV     A,M
04BE 23                 INX     H
04BF 226C01             SHLD    PAGER
04C2 6F                 MOV     L,A         ;MOVE TO L
04C3 2600               MVI     H,0         ;CLEAR H
04C5 CD0D05             CALL    BD5         ;CONVERT TO ASCII
04C8 3E2C               MVI     A,','       ;INSERT COMMA
04CA CDF504             CALL    STUFF
04CD C9                 RET                 ;RETURN
                ;***********************************************
                ;       GTTWO - TAKES TWO BYTES OF BINARY DATAA
                ;               CONVERTS THEM TO ASCII IN TBUF
                ;               TBUF IS DUMPED WHEN FULL;
                ************************************************
                GTTWO:
04CE 2A6C01             LHLD    PAGER
04D1 5E                 MOV     E,M         ;GET LSB
04D2 23                 INX     H           ;STEP POINTER
04D3 56                 MOV     D,M         ;GET MSB
04D4 23                 INX     H           ;MOVE POINTER
04D5 226C01             SHLD    PAGER       ;STORE IN PAGER
04D8 EB                 XCHG
04D9 AF                 XRA     A           ;CLEAR A
04DA B4                 ORA     H           ;IS IT NEGATIVE?
```

```
04DB F2EC04          JP      GTT10    ;NO - DO NOT INSERT MIN
04DE 2B              DCX     H        ;DECREMENT
04DF 7C              MOV     A,H      ;GET MSB
04E0 EEFF            XRI     0FFH     ;COMPLEMENT
04E2 67              MOV     H,A      ;
04E3 7D              MOV     A,L      ;GET LSB
04E4 EEFF            XRI     0FFH     ;COMPLEMENT
04E6 6F              MOV     L,A      ;RESTORE LSB
04E7 3E2D            MVI     A,'-'    ;MINUS SIGN
04E9 CDF504          CALL    STUFF    ;INSERT '-'
                GTT10:
04EC CD0D05          CALL    BD5      ;CONVERT TO ASCII
04EF 3E2C            MVI     A,','
04F1 CDF504          CALL    STUFF
04F4 C9              RET
                ;*******************************************
                ;       STUFF - TAKES CHARACTER PRESENT IN A
                ;               INSERTS INTO TBUFF AT LOCATION
                ;               POINTED TO BY POINT
                ;               WHEN POINT = 100H, BUFFER IS DU
                ;*******************************************
                STUFF:
04F5 E5              PUSH    H
04F6 D5              PUSH    D
04F7 C5              PUSH    B
04F8 2A6201          LHLD    POINT
04FB 77              MOV     M,A      ;STORE IN BUFFER
04FC 2C              INR     L
04FD C20605          JNZ     STU10
0500 CDF605          CALL    WRITE
0503 218000          LXI     H,80H
                STU10:
0506 226201          SHLD    POINT
0509 C1              POP     B
050A D1              POP     D
050B E1              POP     H
050C C9              RET
                ********************************************
                *       BINDEC - CONVERTS ONE OR TWO BYTES OF
                *                BINARY DATA TO 5 OR 3 ASCII DE
                *                CHARACTERS
                *               ENTRY: STORAGE ADDRESS IN D,E
                *                       VALUE IN H,L
                ********************************************
                ;
                BD5:
050D AF              XRA     A
050E 326601          STA     WORK
0511 01F0D8          LXI     B,0D8F0H
0514 CD3005          CALL    BDA
                BD4:
```

```
0517 0118FC              LXI     B,0FC18H
051A CD3005              CALL    BDA
                 BD3:
051D 019CFF              LXI     B,0FF9CH
0520 CD3005              CALL    BDA
                 BD2:
0523 01F6FF              LXI     B,0FFF6H
0526 CD3005              CALL    BDA
                 BD1:
0529 7D                  MOV     A,L
052A F630                ORI     30H
052C CDF504              CALL    STUFF
052F C9                  RET
                 BDA:
0530 AF                  XRA     A         ;CLEAR A
                 BDB:
0531 5D                  MOV     E,L
0532 54                  MOV     D,H
0533 3C                  INR     A
0534 09                  DAD     B
0535 DA3105              JC      BDB
0538 3D                  DCR     A
0539 6B                  MOV     L,E
053A 62                  MOV     H,D
053B 47                  MOV     B,A       ;SAVE IN B
053C FE00                CPI     0         ;IS IT A ZERO?
053E C24705              JNZ     BDC       ;NO - STUFF IT
0541 3A6601              LDA     WORK      ;FETCH FLAG
0544 B7                  ORA     A         ;IS IT SET?
0545 C8                  RZ                ;NO - RETURN WITHOUT S
0546 78                  MOV     A,B
                 BDC:
0547 F630                ORI     30H
0549 CDF504              CALL    STUFF
054C 3EFF                MVI     A,0FFH
054E 326601              STA     WORK      ;SET FLAG
0551 C9                  RET
                 ;**
                 ;       DRIVERS - I/O SUBROUTINES CONTAINING
                 ;                 TTY, CRT, DISK, I/O PORTS
                 ;**
                 ;
                 ;               TTY DRIVERS
                 ;
                 TTYIN:
0552 DBF5                IN      TSTAT     ;FETCH STATUS
0554 E602                ANI     RXRDY     ;IS RECEIVER READY WITH
0556 CA5205              JZ      TTYIN     ;NO KEEP LOOKING
0559 DBF4                IN      TDATA     ;FETCH DATA BYTE
055B C9                  RET               ;RETURN WITH BYTE IN A
                 TTYOUT:
```

```
055C F5                 PUSH     PSW       ;SAVE DATA BYTE
055D DBF5               IN       TSTAT     ;FETCH STATUS
055F E601               ANI      TXRDY     ;TRANSMITTER READY FORB
0561 CA5C05             JZ       TTYOUT    ;NO - WAIT UNTIL READY
0564 F1                 POP      PSW       ;BRING BACK DATA BYTE
0565 D3F4               OUT      TDATA     ;OUTPUT TO TTY
0567 C9                 RET                ;RETURN
                CRTIN:
0568 DBF7               IN       CSTAT     ;FETCH CRT STATUS
056A E602               ANI      RXRDY     ;RECEIVER READY WITH BY
056C CA6805             JZ       CRTIN     ;NO - WAIT UNTIL READY
056F DBF6               IN       CDATA     ;FETCH INPUT BYTE
                CRTOUT:
0571 F5                 PUSH     PSW       ;SAVE DATA BYTE
                CRT1:
0572 DBF7               IN       CSTAT     ;FETCH CRT STATUS
0574 E601               ANI      TXRDY     ;TXMITTER READY FOR BYE
0576 CA7205             JZ       CRT1      ;NO - WAIT UNTIL READY
0579 F1                 POP      PSW       ;BRING BACK DATA
057A D3F6               OUT      CDATA     ;OUTPUT DATA
057C C9                 RET                ;RETURN
                PRINT:
057D 0E09               MVI      C,9       ;SET UP FOR BDOS CALL
057F C30500             JMP      ENTRY     ;JUMP TO BDOS
                PNIB:
0582 E60F               ANI      0FH       ;MASK LOW 4 BITS
0584 FE0A               CPI      10
0586 D28E05             JNC      P10
0589 C630               ADI      '0'
058B C37105             JMP      CRTOUT
                P10:
058E C637               ADI      'A' - 10
0590 C37105             JMP      CRTOUT
                PHEX:
0593 F5                 PUSH     PSW
0594 0F                 RRC
0595 0F                 RRC
0596 0F                 RRC
0597 0F                 RRC
0598 CD8205             CALL     PNIB
059B F1                 POP      PSW
059C CD8205             CALL     PNIB
059F C9                 RET
                PRHL:
05A0 E5                 PUSH H
05A1 7C                 MOV      A,H
05A2 CD9305             CALL     PHEX
05A5 E1                 POP      H
05A6 E5                 PUSH     H
05A7 7D                 MOV      A,L
05A8 CD9305             CALL     PHEX
```

```
05AB E1                 POP     H
05AC C9                 RET
               CRLF:
05AD 3E0D               MVI     A,0DH    ;CARRIAGE RETURN
05AF CD7105             CALL    CRTOUT
05B2 3E0A               MVI     A,0AH    ;LINE FEED
05B4 C37105             JMP     CRTOUT
               INTIAL:
05B7 0E0D               MVI     C,13
05B9 C30500             JMP     ENTRY
               LOGA:
05BC 110000             LXI     D,00H
05BF 0E0E               MVI     C,14
05C1 C30500             JMP     ENTRY
               LOGB:
05C4 110100             LXI     D,01H
05C7 0E0E               MVI     C,14
05C9 C30500             JMP     ENTRY
               OPEN:
05CC 115C00             LXI     D,05CH
05CF 0E0F               MVI     C,15
05D1 C30500             JMP     ENTRY
               CLOSE:
05D4 115C00             LXI     D,05CH
05D7 0E10               MVI     C,16
05D9 C30500             JMP     ENTRY
               READ:
05DC 115C00             LXI     D,05CH
05DF 0E14               MVI     C,20
05E1 CD0500             CALL    ENTRY
05E4 B7                 ORA     A
05E5 C8                 RZ               ;RETURN IF NO READ ERRB
05E6 3D                 DCR     A        ;IS IT AN EOF?
05E7 C2F005             JNZ     RD010    ;NO MUST BE UNWRITTEN B
05EA 3E0F               MVI     A,0FH    ;SET EOF FLAG
05EC 325B01             STA     EOFLG    ;
05EF C9                 RET
               RD010:
05F0 110301             LXI     D,MSG1   ;'READ ERROR'
05F3 C3BF06             JMP     ERREX
               WRITE:
05F6 115C00             LXI     D,05CH
05F9 0E15               MVI     C,21
05FB CD0500             CALL    ENTRY
05FE B7                 ORA     A
05FF C8                 RZ               ;RETURN IF NO WRITE ERB
0600 3D                 DCR     A        ;
0601 C20A06             JNZ     WR010
0604 110F01             LXI     D,MSG2   ;'WRITE ERROR'
0607 C3BF06             JMP     ERREX
               WR010:
```

```
060A 3D                 DCR     A
060B C21406             JNZ     WR020
060E 111C01             LXI     D,MSG3   ;'DISK FULL'
0611 C3BF06             JMP     ERREX
              WR020:
0614 112701             LXI     D,MSG4   ;'DIRECTORY FULL'
0617 C3BF06             JMP     ERREX
              DELET:
061A 0E13               MVI     C,19
061C 115C00             LXI     D,05CH
061F C30500             JMP     ENTRY
              MAKE:
0622 115C00             LXI     D,05CH
0625 0E16               MVI     C,22
0627 CD0500             CALL    ENTRY
062A 3C                 INR     A
062B C0                 RNZ
062C 112701             LXI     D,MSG4   ;'DIRECTORY FULL'
062F C3BF06             JMP     ERREX
              SEARCH:
0632 115C00             LXI     D,05CH
0635 0E11               MVI     C,17
0637 C30500             JMP     ENTRY
              SETDMA:
063A 0E1A               MVI     C,26
063C C30500             JMP     ENTRY
              ;*********************************************
              ;         SETFCB - MOVES AN INITIALIZATION BLOCKI
              ;                   TFCB AREA
              ;                  ENTRY:  D,E = FILNAME BLOCK
              ;*********************************************
              ;
              SETFCB:
063F E5                 PUSH    H        ;SAVE
0640 215C00             LXI     H,05CH   ;DEFAULT FILE CONTROL B
0643 C5                 PUSH    B        ;SAVE
0644 0613               MVI     B,19     ;SET COUNTER
              SETF1:
0646 1A                 LDAX    D        ;FETCH BYTE TO BE TRANS
0647 77                 MOV     M,A      ;STORE IN TFCB AREA
0648 23                 INX     H        ;INCREMENT H
0649 13                 INX     D        ;INCREMENT D
064A 05                 DCR     B        ;FINISHED?
064B C24606             JNZ     SETF1    ; NO - GO FOR ANOTHER B
064E AF                 XRA     A        ;CLEAR ACCUM
064F 327C00             STA     TFCB+32
0652 C1                 POP     B
0653 E1                 POP     H
0654 C9                 RET
              ;*********************************************
              ;*        RDFILE - READ AN ENTIRE FILE INTO CONTB
```

```
                    ;*              MEMORY
                    ;*            ENTRY: STARTING ADDRESS OF MEMB
                    ;*                   IN H,L
                    ;*                    ADDRESS OF FILENAME BLO
                    ;*****************************************
                    ;
                    RDFILE:
0655 226C01                 SHLD    PAGER    ;STORE CURRENT POINTER
0658 CD3F06                 CALL    SETFCB
065B CDCC05                 CALL    OPEN     ;OPEN FILE
065E AF                     XRA     A        ;CLEAR ACCUM
065F 325B01                 STA     EOFLG    ;CLEAR EOF FLAG
                    RDF10:
0662 2A6C01                 LHLD    PAGER    ;FETCH CURRENT POINTER
0665 EB                     XCHG             ;PUT POINTER IN D,E
0666 CD3A06                 CALL    SETDMA
0669 CDDC05                 CALL    READ     ;READ A RECORD
066C CDAE06                 CALL    HAFPG    ;MOVE PAGE INDEX
066F 3A5B01                 LDA     EOFLG    ;FETCH EOF FLAG
0672 B7                     ORA     A        ;EOF FOUND?
0673 CA6206                 JZ      RDF10    ;NO - READ ANOTHER PAGE
0676 CDD405                 CALL    CLOSE    ;CLOSE FILE
0679 C9                     RET              ;RETURN
                    ;*****************************************
                    ;       WRFILE - WRITE A BLOCK OF MEMORY IN A E
                    ;               ENTRY:  NUMBER OF RECORDS+1 TOW
                    ;                       STARTING ADDRESS IN H,L
                    ;*****************************************
                    ;
                    WRFILE:
067A 226C01                 SHLD    PAGER    ;SET UP PAGER
067D CD3F06                 CALL    SETFCB   ;SET FCB
0680 118000                 LXI     D,80H
0683 CD3A06                 CALL    SETDMA
0686 CD3206                 CALL    SEARCH   ;SEARCH FOR EXISTING FI
0689 3C                     INR     A        ;WAS THERE A MATCH?
068A C29006                 JNZ     WRF05    ;YES - SKIP MAKE FUNCTO
068D CD2206                 CALL    MAKE     ;MAKE DIRECTORY ENTRY
                    WRF05:
0690 CDCC05                 CALL    OPEN     ;OPEN FILE
                    WRF10:
0693 2A6C01                 LHLD    PAGER    ;FETCH CURRENT POINTER
0696 EB                     XCHG             ;PUT POINTER IN D,E
0697 CD3A06                 CALL    SETDMA
                    WRF15:
069A CDF605                 CALL    WRITE    ;WRITE A RECORD
069D CDAE06                 CALL    HAFPG    ;MOVE PAGE INDEX
06A0 3A6E01                 LDA     RCDS     ;FETCH NUMBER OF RECORD
06A3 216B00                 LXI     H,TFCB+15
06A6 BE                     CMP     M
06A7 C29A06                 JNZ     WRF15    ;NO - WRITE ANOTHER REC
```

```
06AA CDD405             CALL    CLOSE    ;CLOSE THE FILE
06AD C9                 RET              ;     RETURN
                ;*****************************************
                ;       SUBROUTINE HAFPGE - ADJUSTS DMA ADDRESS
                ;               HALF PAGE OF MEMORY
                ;*****************************************
                ;
                HAFPG:
06AE E5                 PUSH    H        ;SAVE
06AF 2A6C01             LHLD    PAGER
06B2 118000             LXI     D,0128   ;
06B5 19                 DAD     D        ;ADD 128 TO PAGER
06B6 226C01             SHLD    PAGER    ;RESTORE UPDATED PAGER
06B9 EB                 XCHG             ;SWITCH H,L WITH D,E
06BA CD3A06             CALL    SETDMA   ;SET DMA
06BD E1                 POP     H
06BE C9                 RET
                ;**
                ;       ERREX - FATAL ERRORS EXIT VIA THIS ROUT
                ;               ENTRY: D,E CONTAIN MESSAGE ADDR
                ;               EXIT:   BOOT TO DOS
                ;**
                ;
                ERREX:
06BF CD7D05             CALL    PRINT    ;PRINT THE MESSAGE
06C2 115C00             LXI     D,TFCB   ;TEMPORARY FCB
06C5 CDD405             CALL    CLOSE    ;CLOSE THE FILE
06C8 C30000             JMP     BOOT     ;BOOT TO DOS
06CB            END     100H

A>
```

```
REM***********************************************************
REM     REDUCE - EXTRACTS FOURIER COEFFICIENTS
REM                OF ODD HARMONICS FROM GIVEN DATA FILE
REM***********************************************************
DELTA.T = 85E-6
PI = 3.141592654
CONTR$="B:CONTROL"
DATUM.PTS$="B:DATA.ASC"
OUTPUT$="B:OUTPUT"
TAB$ = "  "
FILE DATUM.PTS$
IF END # 1 THEN 200
READ # 1; ICHNL,FCHNL,SV0,SV1,SCANS,SCAN.PERIOD,RECORD.FREQ
SCAN.PERIOD = SCAN.PERIOD * .9765625E-3
PRINT "INITIAL ANALOG CHANNEL",ICHNL
PRINT "FINAL ANALOG CHANNEL",FCHNL
PRINT
PRINT "SCANIVALVE ZERO SETTING",SV0
PRINT "SCANIVALVE ONE SETTING ",SV1
PRINT
PRINT "NUMBER OF SCANS ",SCANS
PRINT "SCAN PERIOD",SCAN.PERIOD;" SECONDS"
PRINT "SCAN RATE",1/SCAN.PERIOD;" HZ"
RECORD.FREQ=RECORD.FREQ/10
PRINT "RECORDED REFERENCE FREQUENCY ",RECORD.FREQ
REM*********************************************************
REM     READ IN ASCII DATA FILE
REM*********************************************************
DIM DAT(FCHNL+1,SCANS),PHASE(FCHNL+1),A(FCHNL+1),B(FCHNL+1)
READ # 1;DUMMY,DUMMY,DUMMY
PRINT
FOR I= 1 TO SCANS
READ #1;TIME
FOR J=ICHNL TO FCHNL
READ #1;DAT(J,I)
NEXT J
NEXT I
REM*********************************************************
REM     COMPUTE LAST DATA SAMPLE NUMBER TO BE USED
REM*********************************************************
OMEGA = 2*PI*RECORD.FREQ
DRIVE.PERIOD = 1/RECORD.FREQ
N = INT((DRIVE.PERIOD/SCAN.PERIOD)\
        *INT((SCANS*SCAN.PERIOD)/DRIVE.PERIOD))
PRINT "NUMBER OF DATA POINTS USED ";N,"AVAILABLE ";SCANS
REM*********************************************************
REM     COMPUTE FOURIER COEFFICIENTS
REM*********************************************************
HIHARMONIC = INT(DRIVE.PERIOD/SCAN.PERIOD/2)
IF HIHARMONIC > 5 THEN HIHARMONIC = 5
PRINT "HIGHEST HARMONIC EXTRACTED ";HIHARMONIC
```

```
FOR INDEX = 0 TO HIHARMONIC
FOR J=ICHNL TO FCHNL
A(J)=0
B(J)=0
NEXT J
FOR I = 1 TO N
FOR J=ICHNL TO FCHNL
      X1= INDEX*OMEGA*((I-1)*SCAN.PERIOD+DELTA.T*J)
      B(J)=B(J)+DAT(J,I)*SIN(X1)
      A(J)=A(J)+DAT(J,I)*COS(X1)
NEXT J
NEXT I
REM******************************************************
REM              OUTPUT
REM******************************************************
PRINT "FOURIER COEFFICIENTS FOR HARMONIC ";INDEX
PRINT"CHANNEL","COS","SIN","PHASE ","MAG"
FOR J=ICHNL TO FCHNL
PHASE(J)=ATN(B(J)/A(J))
IF A(J)<0 AND B(J)>0 THEN PHASE(J)=PHASE(J)+PI
IF A(J)<0 AND B(J)<0 THEN PHASE(J)=(PHASE(J)-PI)
IF INDEX = 0 THEN A(J) = A(J)/2
MAG= SQR((ABS(A(J)))↑2+(ABS(B(J)))↑2)/2.048/I
IF INDEX = 1  AND J = 0  THEN FASE = PHASE(0)
PHASE(J)=PHASE(J)-FASE
IF PHASE(J)<-PI THEN PHASE(J)=PHASE(J)+2*PI
IF PHASE(J)>PI THEN PHASE(J)=PHASE(J)-2*PI
PRINT J,A(J)/2.048/I,B(J)/2.048/I,180*PHASE(J)/PI,MAG
NEXT J
PRINT
NEXT INDEX
200 STOP
END
```

```
 /* CP/CMS INTERFACE PROGRAM */
DECLARE BOOT LITERALLY '0H', BDOS LITERALLY '05H';
DECLARE
    LIT LITERALLY 'LITERALLY',
   OPAD LITERALLY '13',   /* NUMBER OF RUBOUTS ON OUTPUT AFTER LF */
   OPADV BYTE,            /* REMAINING PAD CHARS TO SEND */
    PAD LIT '1',  /* NUMBER OF PAD CHARS AFTER PROMPT */
    HALFDUP LIT '1', /* TRUE IF HALF DUPLEX */
    BEEP LIT '07H',
    BREAK LIT '0',
    RUBOUT LIT '7FH',
    CTLB LIT '02H',
    CTLL LIT '0CH',
    CTLC LIT '3',
    CTLI LIT '09H',
    CTLT LIT '14H',
    CTLU LIT '15H',
    CTLQ LIT '11H',
    CTLR LIT '12H',
    CTLE LIT '05H',
    CTLW LIT '17H',
    ATTEN LIT 'CTLQ',
    CTLJ LIT '0AH',
    ATSIGN LIT '40H',
    BACKSPACE LIT 'ATSIGN',
    ENDFILE LIT '1AH',
    PROMPT LIT '''>''',
    EOBLOCK LIT '25H',  /* END BLOCK (PERCENT) */
    XOFF LIT '13H',
    EOL LIT 'XOFF',  /* END OF LINE CHAR */
    NULL LIT 'XOFF'; /* NULL CHARACTER FROM COMPUTER */

DECLARE FCBA LIT '5CH',
    FCBADR ADDRESS INITIAL(FCBA),
    FCB BASED FCBADR BYTE,
    BUFFA ADDRESS INITIAL(80H),
    MAXMBP ADDRESS INITIAL(05H),
    MAXM BASED MAXMBP ADDRESS,
    BUFF BASED BUFFA BYTE;
100H:
    /* DISK OUTPUT ROUTINES */
MON1: PROCEDURE(F,A);
    DECLARE F BYTE, A ADDRESS;
    GO TO BDOS;
    END MON1;

LIFTHEAD: PROCEDURE;
```

```
    CALL MON1(12,0);
    END LIFTHEAD;

MON2: PROCEDURE(F,A) BYTE;
    DECLARE F BYTE, A ADDRESS;
    GO TO BDOS;
    END MON2;

  DECLARE DCNT BYTE;

OPEN: PROCEDURE(FCB);
    DECLARE FCB ADDRESS;
    DCNT = MON2(15,FCB);
    END OPEN;

CLOSE: PROCEDURE(FCB);
    DECLARE FCB ADDRESS;
    DCNT = MON2(16,FCB);
    END CLOSE;

DELETE: PROCEDURE(FCB);
    DECLARE FCB ADDRESS;
    CALL MON1(19,FCB);
    END DELETE;

DISKWRITE: PROCEDURE(FCB);
    DECLARE FCB ADDRESS;
    DCNT = MON2(21,FCB);
    CALL LIFTHEAD;
    END DISKWRITE;

MAKE: PROCEDURE(FCB);
    DECLARE FCB ADDRESS;
    DCNT =MON2(22,FCB);
    END MAKE;

DISKREAD: PROCEDURE(FCB);
    DECLARE FCB ADDRESS;
    DCNT = MON2(20,FCB);
    CALL LIFTHEAD;
    END DISKREAD;


DECLARE DCOPY BYTE,
    /* 0 IF NO COPY
       1 IF RECEIVING
       2 IF SUSPENDED RECEIVE
       3 IF TRANSMITTING
```

```
       4 IF SUSPENDED TRANSMIT
    */
    LASTLF BYTE,
    OBP BYTE;    /* OUTPUT BUFFER POINTER */

DECLARE MBP ADDRESS;  /* MEMORY BUFFER POINTER */

    /* CRT AND TTY DRIVERS */

DECLARE
    PROC LIT 'PROCEDURE',
    LOGICAL LIT 'BYTE',
    FIXED LIT 'ADDRESS',
    TRUE LIT '1',
    FALSE LIT '0',
    FOREVER LIT 'WHILE TRUE',

    /* I/O CONSTANTS */
    CR LIT '0DH',
    LF LIT '0AH',

    TTI LIT '0F4H',  TTO LIT '0F4H',  TTS LIT '0F5H',  TTC LIT '0F5H',
    CRI LIT '0F6H',  CRO LIT '0F6H',  CRS LIT '0F7H',  CRC LIT '0F7H';

CRTINR: PROC LOGICAL;
    /* CRT INPUT DATA READY */
    RETURN ROR(INPUT(CRS),1);
    END CRTINR;

CRTOUTR: PROC LOGICAL;
    /* CRT OUTPUT READY */
    RETURN INPUT(CRS);
    END CRTOUTR;

TTYINR: PROC LOGICAL;
    /* TTY INPUT READY */
    RETURN ROR (INPUT(TTS),1);
    END TTYINR;

TTYOUTR: PROC LOGICAL;
    /* TTY OUTPUT READY */
    RETURN INPUT(TTS);
    END TTYOUTR;

CRTRD: PROC BYTE;
    /* CRT DATA IN */
    RETURN  INPUT(CRI) AND 7FH;
    END CRTRD;
```

```
CRTWR: PROC(B);
    DECLARE B BYTE;
    /* CRT WRITE */
    IF B >= ' ' OR B = CR OR B = LF THEN
         OUTPUT(CRO) =  B;
    IF B = LF THEN OPADV = OPAD;
    END CRTWR;

TTYRD: PROC BYTE;
    /* READ TTY */
    RETURN  INPUT(TTI) AND 7FH;
    END TTYRD;

TTYWR: PROC(B);
    CECLARE B BYTE;
    /* TTY WRITE */
    OUTPUT(TTO) =  B;
    END TTYWR;

TTYOUT: PROCEDURE(B);
    DECLARE B BYTE;
        DO WHILE NOT TTYOUTR;
        END;
    CALL TTYWR(B);
    END TTYOUT;


CRTOUT: PROC(B);
    DECLARE B BYTE;
        DO WHILE NOT CRTOUTR;
        END;
    CALL CRTWR(B);
    END CRTOUT;

CRLF: PROC;
    CALL CRTOUT(CR);
    CALL CRTOUT(LF);
    /* WAIT FOR CRT TO RESPOND TO LF */
        DO WHILE OPADV > 0; OPADV = OPADV - 1;
        CALL CRTOUT(0);
        END;
    END CRLF;

CRTPR: PROC(A);
    /* WRITE MESSAGE AT A UNTIL $ */
    DECLARE A ADDRESS, M BASED A BYTE;
    CALL CRLF;
```

```
          DO WHILE M <> '$';
          CALL CRTOUT(M); A=A+1;
          END;
      CALL CRLF;
      END CRTPR;

   DECLARE
      BEEPED LOGICAL,          /* TRUE IF "BEEPED" CRT */
      NCHARS BYTE,             /* CHARS TRANSMITTED SINCE LF */
      WAITRESP LOGICAL,       /* WAITING FOR '>' */
      SENDXOFF LOGICAL,      /* SEND XOFF */
      RESPOND LOGICAL,        /* RESPOND TO '>' */
      NPAD BYTE,             /* PAD CHARACTERS REMAINING AFTER PROMPT*/
      CHAR BYTE,               /* CURRENT CRT CHARACTER */
      CRTBUFF(254) BYTE,         /* BUFFER FOR CRT INPUT */
      CRTN         BYTE,         /* NUMBER OF BUFFERED CHARS */
      CRTBPF       BYTE,         /* NEXT CHARACTER TO TRANSMIT */
      CRTBPL       BYTE,         /* NEXT CHARACTER TO FILL */

      /* TTY BUFFERS - FROM TTY TO CRT */
      TTYBUFF(254) BYTE,
      TTYN         BYTE,
      TTYBPF       BYTE,
      TTYBPL       BYTE;

   INTBPF: PROC;
      /* INCREMENT TTY FRONT POINTER */
      TTYN = TTYN - 1;
      IF (TTYBPF := TTYBPF + 1) > LAST (TTYBUFF) THEN
          TTYBPF = 0;
      END INTBPF;

   INTBPL: PROC;
      /* INCREMENT LAST POSITION OF TTY BUFFER */
      IF (TTYN := TTYN + 1) > LAST(TTYBUFF) THEN
          DO; CALL CRTPR(.'BUFFER OVERFLOW $');
          TTYN, TTYBPF, TTYBPL = 0;
          END; ELSE
      IF (TTYBPL := TTYBPL + 1) > LAST (TTYBUFF) THEN
          TTYBPL = 0;
      END INTBPL;

   BUFFTTY: PROC;
      /* BUFFER CHARACTER FROM TTY TO CRT */
      TTYBUFF(TTYBPL) = CHAR;
      CALL INTBPL;
      END BUFFTTY;
```

```
ZERO: PROC;
    BEEPED, WAITRESP, SENDXOFF, RESPOND = FALSE;
    NPAD, NCHARS, CRTN, CRTBPF, CRTBPL, TTYN, TTYBPF, TTYBPL = 0;
    CPADV = 0;
    END ZERO;

INCBPF: PROC;
    /* INCREMENT CRTBPF */
    CRTN = CRTN - 1;
    IF (CRTBPF := CRTBPF + 1) > LAST(CRTBUFF) THEN
        CRTBPF = 0;
    END INCBPF;

INCBPL: PROC;
    /* INCREMENT CRTBPL */
    CRTN = CRTN + 1;
    IF (CRTBPL := CRTBPL + 1) > LAST(CRTBUFF) THEN
        CRTBPL = 0;
    END INCBPL;

SETFCBR: PROCEDURE;
    FCB(32) = 0;
    END SETFCBR;

PUTCHAR: PROCEDURE;
    CRTBUFF(CRTBPL) = CHAR;
    CALL INCBPL;
    END PUTCHAR;



FILLBUFF: PROCEDURE(I);
    DECLARE I BYTE; /* FILL BUFFER WITH CHAR I */
    BUFF(OBP) = I;
    IF (OBP := OBP + 1) >= 80H THEN
        DO; CALL DISKWRITE(FCBA);
        IF DCNT <> 0 THEN
            DO; DCOPY = 0;
            CALL CRTPR(.'DISK WRITE ERROR $');
            CALL CLOSE(FCBA);
            END;
        OBP = 0;
        END;
    END FILLBUFF;

DUMPMEM: PROCEDURE;
    /* DUMP MEMORY BUFFER */
    DECLARE I ADDRESS;
```

```
    I = 0;
        DO WHILE MBP <> 0;
        MBP = MBP - 1;
        CALL FILLBUFF(MEMORY(I));
        I = I + 1;
        END;
    END DUMPMEM;


CRTCHAR: PROCEDURE;
    DECLARE LAST BYTE;
    LAST = (CHAR = PROMPT) AND LASTLF;
    IF DCOPY = 1 THEN /* COPY TO DISK */
        DO; IF LAST THEN CALL DUMPMEM;
        MEMORY(MBP) = CHAR;
        IF (MBP := MBP + 1) > MAXMBP THEN
            DO; CALL CRTPR(.':FORCED WRITE$');
            CALL DUMPMEM;
            END;
        END;
    CALL BUFFTTY;
    RESPOND = RESPOND AND NOT( LASTLF AND (CHAR = EOBLOCK));
    IF LAST THEN
        DO; NCHARS = 0;
        IF RESPOND THEN /* AUTO RESPONSE */
            DO; CHAR = ' '; CALL PUTCHAR;
            CHAR = EOL; CALL PUTCHAR;
            END;
        WAITRESP = FALSE; NPAD = PAD;
        END;
    LASTLF = CHAR = LF;
    END CRTCHAR;

CRLFD: PROCEDURE;
    CHAR = CR; CALL CRTCHAR;
    CHAR = LF; CALL CRTCHAR;
    END CRLFD;


GETCHAR: PROCEDURE;
    CHAR = 0;
    IF DCOPY = 3 THEN /* TRANSMIT DATA */
        DO; /* READ NEXT CHARACTER FROM INPUT BUFFER */
        IF OBP >= 80H THEN
            DO; OBP = 0;
            CALL DISKREAD(FCBA);
            IF DCNT = 1 THEN BUFF,DCOPY = 0; ELSE
            IF DCNT > 1 THEN
```

```
                DO; CALL CRTPR(.'DISK READ ERROR$');
                DCOPY = 0;
                FND;
            END;
        IF (CHAR := BUFF(OBP)) = ENDFILE THEN
            CHAR, DCOPY = 0;
        OBP = OBP + 1;

        END;

    IF CHAR = 0 AND CRTN > 0 THEN
        DO; CHAR = CRTBUFF(CRTBPF);
        CALL  INCBPF;
        END;

    /* IGNORE LINE FEEDS (MAY BE FROM FILE) */
    IF CHAR = LF THEN CHAR = 0;
    IF (SENDXOFF := (CHAR = CR)) THEN
        DO;  CHAR = EOL;
        END; ELSE
    IF (CHAR <> 0) AND HALFDUP THEN CALL CRTCHAR;
    END GETCHAR;

RECEIVE: PROCEDURE;
    IF DCOPY = 2 THEN DCOPY = 1; ELSE
    IF DCOPY <> 0 THEN CALL CRTPR(.'OUTPUT IN PROGRESS$');
    ELSE
    DO;
    CALL SETFCBR;
    CALL DELETE(FCBA); CALL MAKE(FCBA);
    CALL OPEN(FCBA);
      IF DCNT = 255 THEN
        CALL CRTPR(.'CANNOT OPEN FILE$'); ELSE
        DCOPY = 1;
    LASTLF = FALSE; OBP,MBP = 0;
    END;
    END RECEIVE;

FINIS: PROCEDURE;
    IF DCOPY = 0 THEN
        CALL CRTPR(.'NO I/O IN PROGRESS$'); ELSE
    IF DCOPY < 3 THEN
        DO; CALL DUMPMEM;
            DO WHILE OBP <> 0;
            CALL FILLBUFF(ENDFILE);
            END;
        CALL CLOSE(FCBA);
        END;
```

```
    DCOPY = 0;
    END FINIS;

TRANSMIT: PROCEDURE;
    IF DCOPY = 4 THEN DCOPY = 3; ELSE
    IF DCOPY <> 0 THEN
        CALL CRTPR(.'I/O IN PROGRESS$');
    ELSE
        DO; CALL SETFCBR;
        CALL OPEN(FCBA);
        IF DCNT = 255 THEN
            CALL CRTPR(.'CANNOT OPEN INPUT$');
        ELSE
            DO; OBP = 80H; DCOPY = 3;
            END;
        END;
    END TRANSMIT;
 /* TYPE INITIAL MESSAGE, AND LOOP */
CALL CRTPR(.'READY.$');

MAXMBP = MAXM; /* SET LARGEST VALUE OF MBP */
NCHARS , DCOPY = 0;
CALL ZERO;

    DO FOREVER;
    IF CRTINR THEN /* INPUT AT THE CRT */
        DO;
        IF CRTN = LENGTH(CRTBUFF) THEN /* OVERFLOW */
            DO;
            IF NOT BEEPED THEN
                DO;
                IF (BEEPED := CRTOUTR) THEN
                CALL CRTOUT(BEEP);
                END;
            END; ELSE /* SAVE CHARACTER IN CRTBUFF */
            DO;
            /* CHECK FOR SPECIAL CHARACTERS */
            IF (CHAR := CRTRD) = RUBOUT THEN
                DO; IF CRTN > 0 THEN
                    DO; CRTN = CRTN - 1;
                    IF (CRTBPL := CRTBPL - 1) = 255 THEN
                        CRTBPL = LAST(CRTBUFF);
                    END; ELSE
                    DO;
                    CHAR = BACKSPACE; CALL PUTCHAR;
                    END;
                END; ELSE
            IF CHAR = BREAK THEN
```

```
            DO; CALL ZERO; CALL TTYOUT(ATTEN);
            IF DCOPY = 1 OR DCOPY = 3 THEN
                 DCOPY = DCOPY + 1;
            END; ELSE
        IF CHAR = CTLU THEN
            DO; CRTN = 0; CHAR = BACKSPACE;
                DO WHILE NCHARS <> 0;
                NCHARS = NCHARS - 1;
                CALL PUTCHAR;
                END;
            END; ELSE
                DO: IF CHAR = CTLL THEN
                    DO; CHAR = EOL; WAITRESP = FALSE;
                    END;
                CALL PUTCHAR;
                END;
        END;
    END; /* OF CRTINR READY TEST */

IF TTYINR THEN /* TTY KEYBOARD IS READY */
    DO;
    IF (CHAR := TTYRD) <> NULL THEN /* COPY */
        DO; IF NPAD > 0 THEN NPAD = NPAD - 1; ELSE
        CALL CRTCHAR;
        END;
    END;

IF TTYOUTR AND (NOT WAITRESP) AND (NPAD = 0) THEN
    DO;
    IF (WAITRESP := SENDXOFF) THEN
         DO; SENDXOFF = FALSE;
         END; ELSE
        DO; CALL GETCHAR;
        IF CHAR <> 0 THEN
            DO;
            IF CHAR = CTLR THEN /* RECEIVE */
                CALL RECEIVE; ELSE
            IF CHAR = CTLT THEN /* TRANSMIT */
                CALL TRANSMIT; ELSE
            IF CHAR = CTLE THEN /* END TR/REC */
                CALL FINIS; ELSE
            IF CHAR = CTLB THEN
                DO;
                RESPOND = TRUE; CALL RECEIVE;
                END; ELSE
            IF CHAR = CTLJ THEN
                DO; IF DCOPY = 3 THEN DCOPY = 4; ELSE
                CALL CRTPR(.'NO INPUT $');
```

```
                RESPOND = FALSE;
                END; ELSE
            IF CHAR = CTLW THEN
               DO; IF DCOPY = 1 THEN DCOPY = 2; ELSE
                IF DCOPY = 3 THEN DCOPY = 4; ELSE
                CALL CRTPR(.'NO I/O IN PROGRESS$');
                END; ELSE
            IF CHAR = CTLC THEN
                DO; IF DCOPY <> 0 THEN
                    CALL FINIS;
                GO TO BOOT;
                END;  ELSE
                DO; NCHARS = NCHARS + 1;
                CALL TTYWR(CHAR);
                END;
            END;
        END;
    END;

IF CRTOUTR THEN /* CHECK FOR BUFFERED OUTPUT */
    DO;
    IF OPADV > 0 THEN
        DO; OPADV = OPADV - 1; CALL CRTWR(0);
        END; ELSE
    IF TTYN > 0 THEN
         DO; CALL CRTWR(TTYBUFF(TTYBPF));
         CALL INTBPF;
         END;
    END;
END; /* OF DO FOREVER */
EOF
```

APPENDIX D

SAMPLE OUTPUT

```
INITIAL ANALOG CHANNEL      0
FINAL ANALOG CHANNEL        4

COORDINATION NUMBER         1

NUMBER OF SCANS             400
SCAN PERIOD  2.929688E-03   SECONDS
SCAN RATE    341.3333  HZ
RECORDED REFERENCE FREQUENCY               10.1

NUMBER OF DATA POINTS USED 371             AVAILABLE 400

FOURIER COEFFICIENTS FOR HARMONIC 0
CHANNEL      COS           SIN             PHASE           MAG
0            2.49391       0               0               2.493908
1            2.434844      0               0               2.434845
2            2.329837      0               0               2.329838
3            2.211704      0               0               2.211705
4            2.316711      0               0               2.316713

FOURIER COEFFICIENTS FOR HARMONIC 1
CHANNEL      COS           SIN             PHASE           MAG
0            -654.6378     -816.6686       0               1046.66
1            -653.8682     -817.2451       5.260612E-02    1046.629
2            -653.5261     -817.6686       8.171639E-02    1046.746
3            -652.9547     -818.0521       .1192551        1046.688
4            -652.5599     -818.2418       .142628         1046.59

FOURIER COEFFICIENTS FOR HARMONIC 2
CHANNEL      COS           SIN             PHASE           MAG
0            1.400119      -3.062779       63.2825         3.367631
1            1.38256       -3.034472       63.21033        3.33459
2            1.54163       -2.995208       65.95031        3.368662
3            1.567927      -2.935155       66.8261         3.327692
4            1.511007      -2.995277       65.46475        3.354618
```

APPENDIX E

OPERATING INSTRUCTIONS

A. ACQUISITION PROCEDURE INSTRUCTIONS

1. Interconnect the following with the MDS-800 using the appropriate cables:
   * Disk Drive
   * CRT
   * BNC Patch Panel
   * Teletype (optional)
2. Attach analog sources to the desired patch panel BNC fitting using coaxial cables. Up to 16 channels may be attached. Ensure voltage limits on analog inputs do not exceed plus or minus 5 volts.
3. With disk drive doors open, power up all equipment.
4. Install the program diskette in Drive A and a blank or uprotected diskette in Drive B, then close the doors.
5. Depress the BOOT switch and momentarily depress the RESET switch.
6. Depress the space bar on the CRT keyboard.
7. Reposition the BOOT switch - The CRT will display the following message: 32K CP/M VERS 1.3
8. Enter ACQUIRE and a carriage return. The program will respond by displaying the current CONTROL file and ask:

"ANY CHANGES?".

9. Respond with a Y for yes or a N for no.

10. If yes, you must then edit the CONTROL file by entering:

```
* ED CONTROL cr
* #A cr
```

Use the editing commands specified in ref. 9.

11. If no, the program will ask for a 4 digit frequency to be entered. The decimal point is understood to be between the first and second significant digits,

    ex: 0105 is equivalent to 10.5 Hz.

12. When ready to record data, enter a carriage return.

13. Repeat steps 11 and 12 until the CONTROL file terminates and asks "GOOD RUN?".

14. Enter Y if you wish to protect the disk from being written to.

15. Entering a N will not protect the diskette nor will it destroy data on the disk.

B. DATA ANALYSIS PROCEDURE INSTRUCTIONS

1. With the DATA diskette in Drive B and the program diskette in Drive A, type in CONVERT DATA.xxx; where xxx is the decimal ID of the data file,

```
CONVERT DATA.001
```

2. When prompted with an A>, enter RUN REDUCE. Output will appear on the selected console device.

APPENDIX F

SAMPLE CONTROL FILE

```
DATE:6/15/77
RUN#: SIN REDUCTION TEST
SCANS PER CHANNEL: 400
SCAN PERIOD: 2
FIRST CHANNEL: 0
LAST CHANNEL: 2
SCANIVALVE 0: 1
SCANIVALVE 0: 6
SCANIVALVE 1: 1
SCANIVALVE 1: 6
CHANNEL 1  = INPUT FROM WAVETEK
CHANNEL 2 AND 3 = OUTPUT FROM OP AMP FILTER
        DATA.000 = 10HZ SIN WAVE ZERO OFFSET
            .001 = 25HZ SIN WITH ZERO OFFSET
            .002 = 35HZ SIN WITH ZERO OFFSET
            .003 = 50HZ SIN WITH ZERO OFFSET
            .004 = 65HZ SIN WITH ZERO OFFSET
            .005 = 75HZ SIN WITH ZERO OFFSET
 $
```

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